THE TECH ENGINEERING NEWS

Massachusetts Institute of Technology • 1937 • *November*

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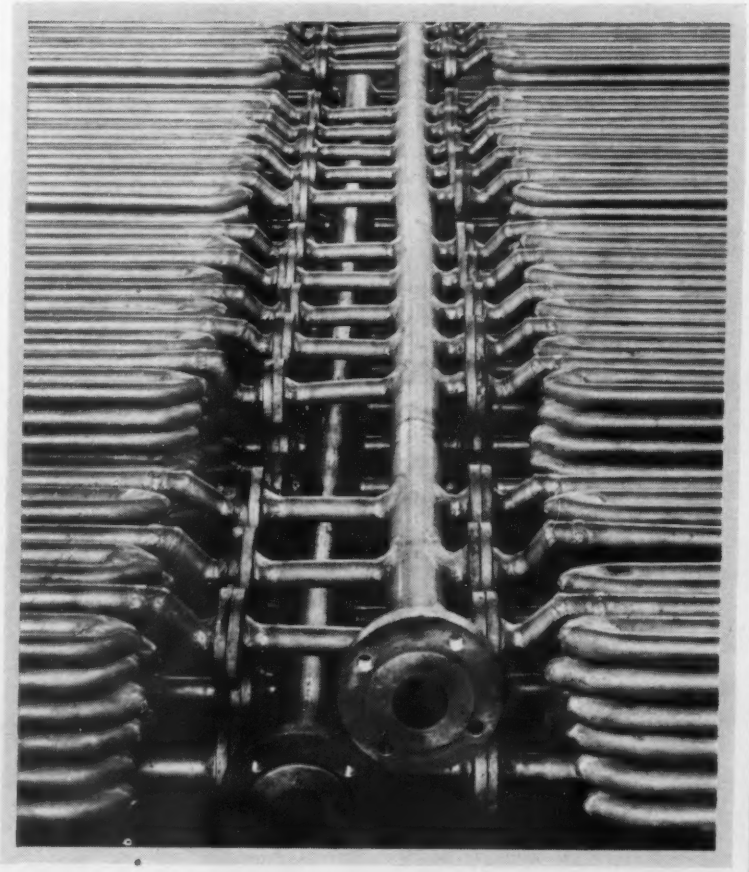

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OUR AUTHORS

WILLIAM A. MUDGE, Works Metallurgist for the Huntington Works of the International Nickel Co., Inc., is well qualified to write on metallurgical topics, since he has been connected with the International Nickel Co., Inc. since 1920. Born in Schenectady, N. Y., he was graduated from Schenectady High School in 1910, and received a B.S. degree from Union College in 1914. Columbia University bestowed a Ph.D. degree upon Dr. Mudge in 1920. During the war, he was a Captain in the 47th Infantry, 4th Division, of the regular army. Dr. Mudge has written various articles on nickel and its alloys, and is the author of the article on nickel in our current issue.

JOHN M. LESSELLS, an Associate Professor of Mechanical Engineering at the Institute, has had an interesting career before coming here. Professor Lessells was born in Scotland, and was educated at Glasgow University. There, he received his B.S. degree, and achieved the honor of being a Lauder scholar. Shortly after his apprenticeship at Dunfermline, he became an inspector in the War Office at London. Professor Lessells has been assistant manager of Armstrong Whitworth, and a special engineer of the Rolls Royce Company in Derby, Upon coming to America, he served as a mechanical engineer in the railway department of the Westinghouse Electric Company, and following this, he was a consulting engineer at Swarthmore, Pa. Among the organizations to which Professor Lessells belongs are the A.S.M.E., and the A.S.T.M. He is the author of numerous technical papers, and collaborated with Professor Timoshenko in producing a paper called "Applied Elasticity."

JOHN C. H. LEE, a Lieutenant Colonel in the Engineering Corps, has served a long and useful career with the army. Colonel Lee was born in Junction City, Kans., and besides his education at the United States Military Academy, he attended the Army Staff College in France, and numerous other army training schools. He was stationed at the Panama Canal from 1909–10, and participated in the survey of Guam, 1913–14, and in the Ohio River Improvement Project of 1915–17. Colonel Lee was a member of General Wood's staff during the war, and has served as District Engineer of Philadelphia since 1934. In addition to being a member of Scabbard and Blade, the A.S.M.E., the A.S.C.E., and the French Legion of Honor, Colonel Lee possesses the D.S.M., and the Croix de Guerre.

IRVING PESKOE, '39, who wrote the article on Pyrotechnics, is a graduate of the Long Branch High School in New Jersey. As a freshman, Mr. Peskoe played on the squash and baseball teams, and is now Contributing Editor of THE TECH ENGINEERING NEWS.

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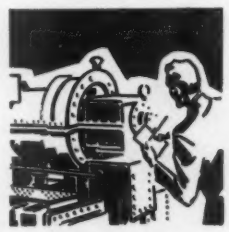

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THE TECH ENGINEERING NEWS
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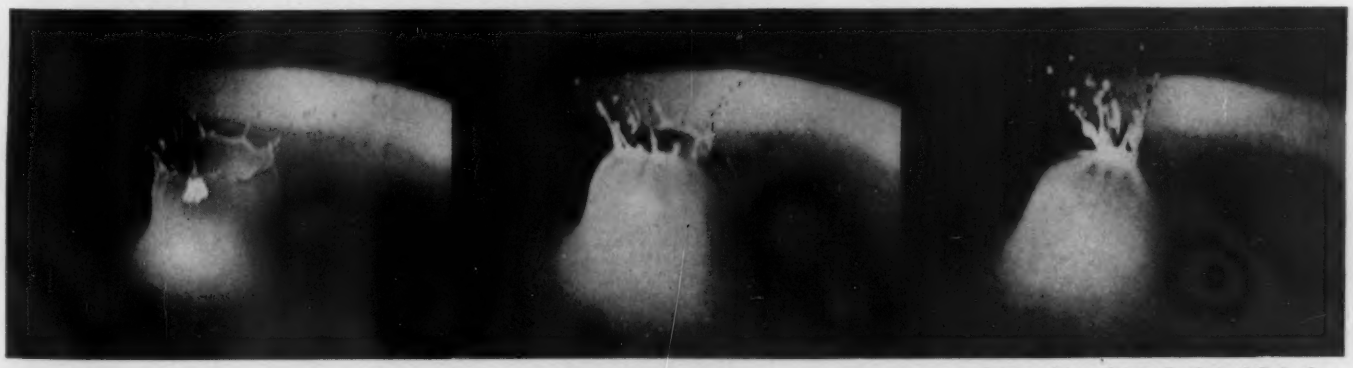
Our Cover This Month

Taken by Robert F. Driscoll, '38, with a Leica, Model G, at the East Boston Airport. It shows the center motor and propellor assemblage of a tri-motor Stinson monoplane. Mr. Driscoll used a Leica No. 2 yellow filter at F:9, 1/60 second.



—Courtesy Massachusetts Institute of Technology

Volume XVIII

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Number 5

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WATER QUENCHING

High Speed Photograph
by Professor H. E. Edgerton.

Nickel and Nickel Alloys

Next to Iron, Nickel Is the Most Important Alloying Element

WILLIAM A. MUDGE

PRIMITIVE man was undoubtedly the first to use nickel. The weapons, with which he replaced stone, were fashioned from meteorites, thus explaining their heavenly origin claimed by the early Arabs and Persians. About 235 B.C. a nickel-copper coin containing 20 per cent of nickel was produced for King Euthydemus II of Bactria. The nickel for this coin, according to Marco Polo, probably came from the copper-nickel mines in the Yunnan Province over the caravan route from Southern China into Bactria, as this route was the early, important trade connection between China and Levant.

Many centuries later, the fourteenth, nickel was discovered in Saxony, Germany, by miners working arsenical copper and silver ores. The white, brittle metal which they produced was extremely difficult to refine, was neither copper nor silver, and was named "Old Nick's Copper." Not until after Cronstedt's discovery of the element, nickel, in 1751, were the secrets of "Old Nick's Copper" and of the seventeenth century's beautiful Paktong clearly understood.

From this time on events moved rapidly. In 1804 Richter produced the first pure nickel and described its properties with great accuracy. Synthetic Paktong was made and sold as German Silver. Faraday's discoveries led eventually to nickel-plating. By 1840 sufficient quantities of nickel were mined in Norway to meet European demands. Twenty years later nickel-copper alloys were being used for coinage. By 1875 the silicate ores in New Caledonia had been discovered and had become the principal source of nickel for the European markets.

—Courtesy International Nickel Co.

Nickel Silver Transom on top of entrance to Goelet Bldg., 608 Fifth Ave., New York, N. Y.

Although some refining of nickel ores had been done in the United States between 1875 and 1885, the nickel industry in North America really began with the discovery of the nickeliferrous pyrrhotite ores at Copper Cliff, near Sudbury, Ontario, Canada in 1886, and the subsequent successful refining of these ores by the Orford process, at Bayonne, N. J.

Nickel was now available in large quantities. Riley's paper, "Alloys of nickel and steel" before the Iron and Steel Institute (British) in 1889, became the impetus for world-wide development of improved steels. At the end of the World War, interest was centered in the development and perfection of alloy steels, most of which contain nickel. The results of these researches and developments have made our modern automobiles, aeroplanes, railroads, and radios possible.

Today, four major metal industries: iron and steel, copper, aluminum, and nickel, — comprise the metallurgical quartet for mechanical progress. Their useful alloys number several thousand and their commercial applications seem almost unlimited. New combinations continue to offer greater possibilities for engineering design. Of the four elements, copper and aluminum are most widely used in the pure, or nearly pure, state; iron and nickel are most widely used in alloy form.

The largest producer of nickel in the world is the International Nickel Company of Canada, Ltd. Its organization includes mines, smelters, and refineries in Canada; a refinery and rolling mill in Huntington, W. Va., and a foundry at Bayonne, N. J.; refineries in Clydach, Wales and Acton, England; and a rolling mill and foundry in Birmingham, England. Technical Information Bureaus are maintained in London, Paris, Brussels, Frankfurt, Milan, Tokyo, and, in the United States, at New York City, Hartford, Detroit, Chicago, and Los Angeles.

The Company's alloy production is limited to nonferrous alloys containing nickel; it does not produce any steels.

The refinery and rolling mill in Huntington, W. Va., has an unusual interest for engineers because of its design and equipment. Here, in addition to malleable nickel, twenty-six important nickel-bearing alloys, all containing at least 50 percent of nickel, are produced in commercial shapes and sizes. Most important of these are Monel, malleable nickel, and Inconel. These will be discussed later. We shall now turn our attention to the properties and uses of nickel.

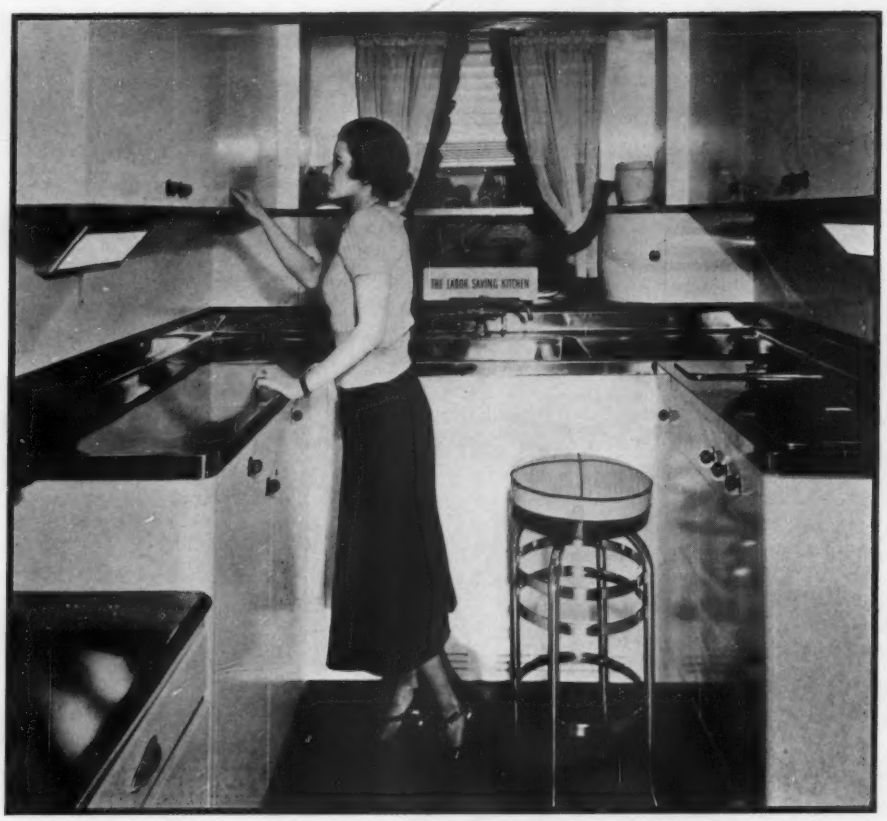
1. *Pure Nickel*

There are four principal uses for pure metallic nickel; as nickel plating, as coinage, as wire and strip elements in radio tubes, and in construction of chemical and food processing equipment. Good resistance to corrosion toward most media, high lustre of polished surfaces, and a medium degree of strength and hardness make the metal especially suitable for these uses.

2. *Nickel alloys with Iron*

(A) Wrought nickel steels are the most important and abundantly used of all alloy steels. Other alloying elements, such as chromium, molybdenum, vanadium, manganese, silicon, and copper are often used along with nickel. The maximum nickel content is about six percent with a usual carbon range of 0.20 to 0.50 percent.

Nickel, chromium, and molybdenum exert the greatest benefit in hardening, strengthening, and toughening steel beyond the capacity of carbon to do so. Nickel accomplishes this effect by entering into solid solution with iron; chromium alters the composition of the carbide constituent in the low chromium hypo-eutectoid steels; molybdenum imparts depth-hardness properties. Nickel also retards grain growth at



This Labor Saving Kitchen is a unit of the General Electric parade of progress. Monel Metal is used for its fixtures because of its stainless properties.

— Courtesy International Nickel Co.

elevated temperatures, thereby permitting a wider range of heating for hot working without damage and a longer exposure above the critical range without important changes in structure. The latter is important in carburization. It should be noted, also, that low nickel steels and nickel-copper steels are more resistant to atmospheric corrosion than carbon steels or even plain copper-bearing steels. Furthermore, nickel steels are more resistant than carbon steel to alkaline solution conditions and, as a consequence, nickel steel boiler tubes are being used to combat certain adverse water conditions. The important uses of nickel alloy steels are in transportation fields — automobile, truck, tractor, aviation, railroad, and marine; for mining machinery, oil producing and refining, prime movers, and power production.

(B) Nickel affects the properties of cast steels similarly to wrought steels. It forms a solid solution with iron and, in amounts up to about five percent in hypo-eutectoid steels, produces a fine-grained structure with increased strength, toughness, and hardness, without loss in ductility. Nickel also suppresses grain growth and segregation. Chromium, molybdenum, manganese, and vanadium are often used with nickel for special additive purposes. Cast nickel-chromium-molybdenum steels possess hardness and wear-resistance derived from the chromium, depth hardening properties from the molybdenum, and strength and toughness from the nickel.

(C) In cast iron, nickel acts in four ways; as a graphitizer, to produce a fine and even grain, to harden the matrix, and to improve resistance to corrosion. Good foundry practice today consists in reducing the silicon content sufficiently to produce sound metal in the heavy sections and to break up carbides, thereby giving machinability in the lighter sections. Many special cast irons have been developed for special properties. The improvement in automotive engine cylinder blocks is an outstanding example of the improvement in cast iron due to alloy additions.

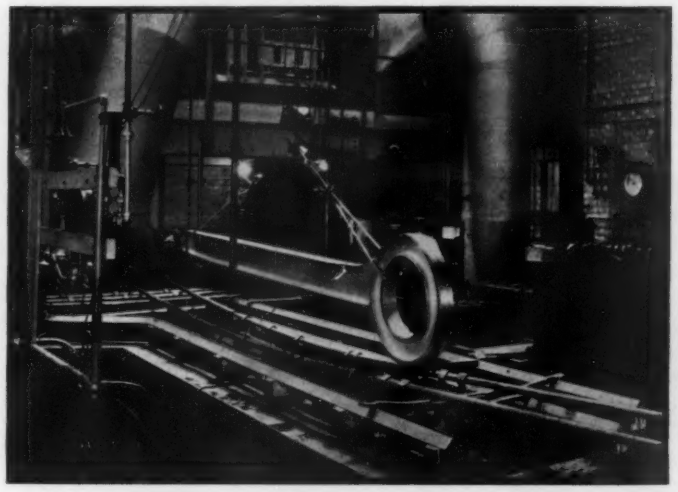
(D) Stainless steel, containing approximately 18 percent of chromium and 8 percent of nickel, is one of the newest and most outstanding developments in alloy steels. The alloy has good mechanical properties, although it cannot be hardened by heat treatment because of its austenitic structure. It has good resistance to atmospheric corrosion and to most oxidizing acid solutions. It is soft when annealed and may be work-hardened to over 300,000 lbs. per sq. inch. Its toughness and endurance limit are also high. Production of this alloy has increased seven-fold in the last ten years. Its fields of usefulness are many and varied, including the architectural and chemical industries which are, perhaps, of major importance.

(E) The important ferro-nickel magnetic alloys are: Permalloy (78% Ni.); Hipernik, Nicaloi, and Copernik (Approx. 50% Ni.). Permalloy is extensively used in the loading of submarine cables where it greatly increases speed of transmission because of its high permeability under very weak magnetizing forces. Hipernik and Nicaloi do not have as high permeabilities as Permalloy, but their initial and maximum permeabilities are ten and twenty-five times, respectively, as high as those of pure iron. Their uses are largely confined to cores of audio-frequency and current transformers. The alloy Copernik has a considerable range of flux density with relatively constant permeability and is familiarly known as "constant permeability nickel."

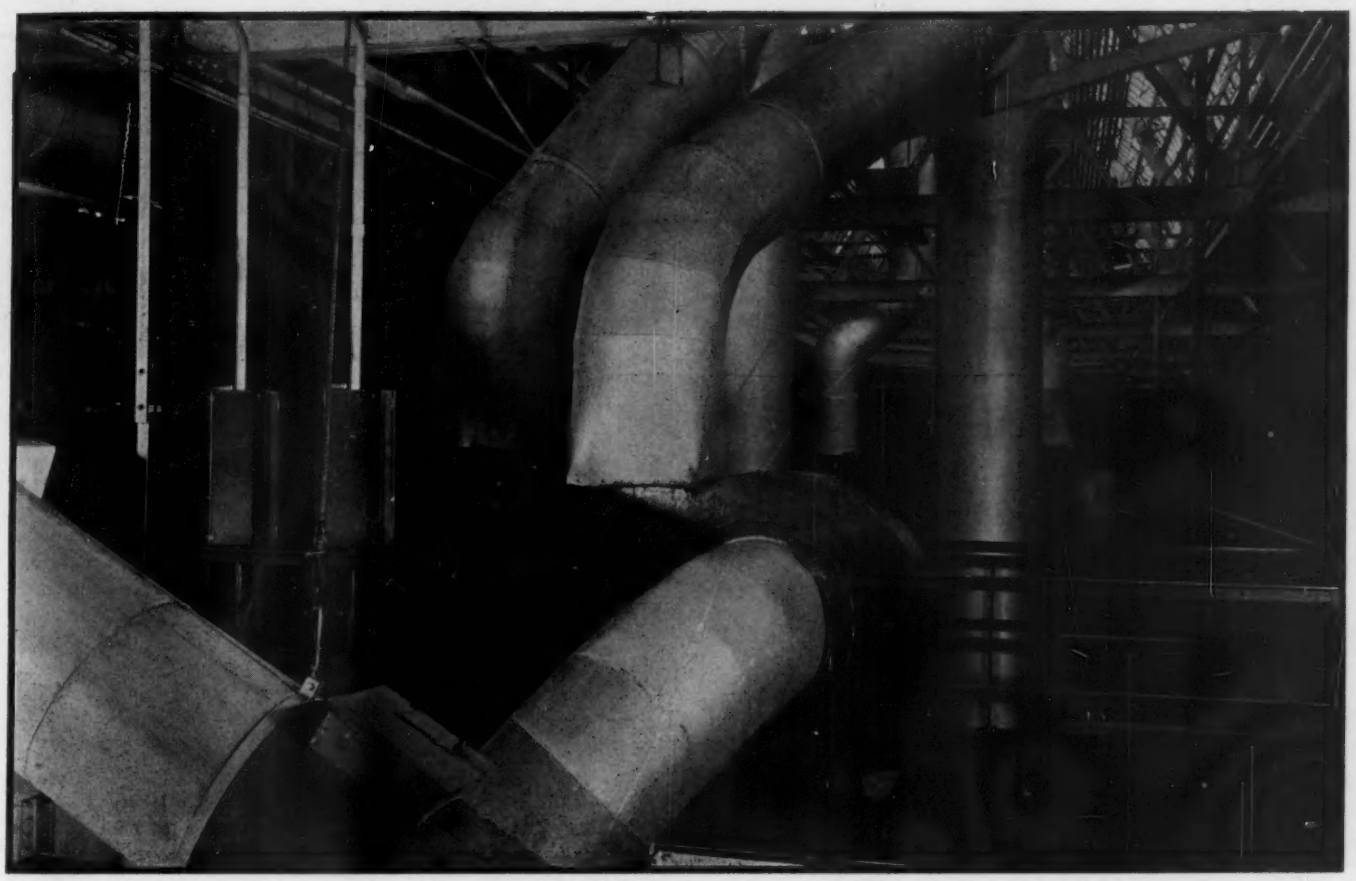
3. *Nickel Alloys with Copper*

(A) The group containing 20 to 50 percent of nickel is better known and includes, principally, the 20 and 30 percent cupro-nickels used for condenser tubes, the 25 percent nickel-copper coinage alloy, the 30 percent nickel-copper for salt water piping, and the 50–50 constantan alloys which are used

— Courtesy International Nickel Co.



A nickel-molybdenum steel locamotive main rod.



— Courtesy International Nickel Co.

These Monel Metal fume ducts are still in use at the Ford Plant after more than a year of exposure to fumes from chromic and muriatic acids.

for pyrometric and electrical purposes. Adnic, which contains 70 percent of copper, 29 percent of nickel and 1 percent of tin, is an interesting modification of the 70–30 condenser tube alloy and has important uses.

(B) Monel, containing approximately 70 percent of nickel and 30 percent of copper, is the most important of all alloys in the third group. It has high strength and hardness and good resistance to corrosion. It is extensively used in the chemical, marine, oil testing, tanning, refrigeration, laundry, photographic, paper and pulp, paint and varnish, and electrical industries. A special grade of Monel is available for automatic high-speed machining operations.

A new and valuable modification of Monel is known as K Monel. The alloy is made by adding an appreciable amount of aluminum to Monel. This produces an alloy which may be age-hardened to tensile strengths greater than 150,000 lbs. per sq. inch. Its corrosion resistance is equal to that of Monel and it is non-magnetic, at temperatures as low as 142° F. Its use is rapidly increasing in industry because of this combination of properties.

4. *Nickel Alloys with Chromium*

There are two very important alloys in this group. The first is the series of well known resistance alloys, containing 15 to 20 percent of chromium, sold under the principal trade names of Nichrome, Chromel, and Brightray. These alloys form the basis of the electrical resistance heating industry throughout the world.

The second alloy in this group is Inconel. It is manufactured solely by the International Nickel Company, Inc. The alloy contains approximately 80 percent of nickel, 14 percent of chromium, and 6 percent of iron. It has been available for about six years in all commercial forms. It has higher mechanical properties than Monel, and its uses for superior resistance to corrosion, and to oxidation at elevated temperatures, are responsible for its steadily increasing production.

5. *Nickel Alloys with Copper and Zinc, and with Copper and Tin*

The nickel-zinc-copper alloys are known as the Nickel Silvers. More than two hundred and fifty of these alloys, containing up to approximately 25 percent of nickel, are produced and widely used because of their white color, and their higher strength and better corrosion resistance than brass. Table flatware and ornamental uses consume large quantities of these alloys.

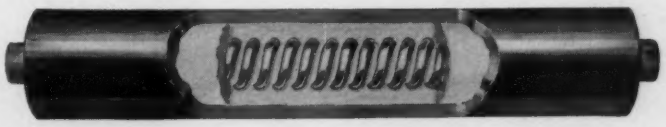
The nickel-tin-copper alloys are known as the nickel bronzes, and are most widely used as casting alloys. Nickel acts in these alloys to improve strength, hardness, toughness, bearing qualities, and resistance to corrosion. Three percent of nickel in a gear bronze, containing 11 percent of tin, will result in an increase of tensile strength of approximately 15 to 20 percent.

6. *Nickel Alloys with Chromium and Iron*

These are the heat resisting alloys and are very numerous. Their chief industrial properties are strength and resistance

(*Continued on page 162*)

— Courtesy General Electric Co.



"Calrod" heating unit made of Inconel, for operating at about 1625° Fahrenheit.

The U. S. Engineer Corps

Flood Control and Harbor Work Are Its Principal Peacetime Duties

LT. COL. JOHN C. H. LEE

TO Technology's graduates, our Army Engineer peacetime work is probably better known than to its students. Technology engineers have been engaged on projects in many of our Districts during recent years, while our work on waterway improvement and protection, on flood control and attendant features, has been arousing wide public interest. Meanwhile, our engineering organization, although expanded to meet the emergency program, has continued essentially the same in principle, and our standards of administration have been upheld as in the past. New techniques, of course, have been developed, as this article attempts to illustrate. Such novel features naturally attract the attention of Technology men throughout this country, and, indeed, in other parts of the world, where, perhaps, is better realized the final importance of American Army engineering experience as a factor in national security.

The value of having an active Corps of Engineers, closely in touch with the engineering profession in civil life, should be appreciated by readers of THE TECH ENGINEERING NEWS, practically all of whom have had military instruction or at least close contact with men enjoying that instruction. Such readers need hardly be reminded that America's proven ability to mobilize her engineering resources in support of her concept of fair dealing holds the profound respect of other governments. Our American Expeditionary Forces' decisive influence on the Western Front in 1918 could not have been possible but for a vast engineering construction program extending from the rebuilt French ports clear up to the front line. It far exceeded the Panama Canal project in magnitude, and yet had to be completed within a fraction of the time. That almost unbelievable task was carried through by our splendid civil engineers, construction superintendents, and contractors, all in uniform for the duration of the emergency, and guided by their brothers of the regular army. The Corps of Engineers thus supplied the vital connecting link between the General Staff and the thousands of emergency engineer officers who had to undergo many adjustments, in war, such as realization of the vital time factor. The regular army engineer fortunately had the confidence of both groups and knew both "languages". He could tell the Staff what was possible to accomplish, and what the engineering powers and limitations were. On the other hand, the constructing engineers knew him, and believed him when he brought back General Pershing's orders laying down what HAD to be accomplished, and WHEN. These Regulars were known to be experienced themselves in handling men and equipment against time and the elements. They thus made effective team work possible. The Allied Staffs saw, and the opposing Command finally realized that the impossible was being achieved, and they have not forgotten. American genius for getting the job done in time saved the situation in 1918.

The military attachés accredited to this country, and other thoughtful foreigners visiting us, seem more interested in our industrial and engineering mobilization plans than in any other phase of our national preparedness. They realize our potential strength even better than we do. Their keen concern is in our ability to change potential into kinetic engineering energy. So long as we are active and progressive we retain their respect. Probably Technology men engaged abroad realize what this means better than those residing in this country.

Our active peacetime organization includes, first of all, military engineers organized into regiments for each division of our Army's field forces, and engineer officers serving in the War Department and in the Army's headquarters overseas, as well as in the decentralized corps areas of the United States, such as the First Corps Area Headquarters in Boston. In each of nine such corps areas and three oversea departments are Regular or National Guard engineer regiments or battalions, both prepared to perform field engineering tasks with the mobile forces, such as the 101st Engineers of the 26th Division. With each Guard divisional regiment is detailed a regular engineer officer to assist in instruction as well as inspections for the War Department. At each of the twelve large headquarters, the Corps Area or Department Engineer supervises the technique of plans and operations from an engineering viewpoint, and, through assistants in the field, carries on the important Reserve training — such as our Reserve Officers' Training Corps work at the Institute. Of course, this is coordinated with other arms as with the Artillery Corps at Technology and, indeed, with the Navy as well. Then we have our graduate student officers obtaining their post-graduate instruction here at Technology and elsewhere under the established system. They also attend the Army's own Engineer School in Virginia (on the same ground where George Washington learned surveying), the Command and General Staff School in Kansas, as well as the Industrial College and the War College in Washington.

All of this obviously military work in time of peace is essential in the training of officers, but without actual engineering experience including responsibility for design and construction, our Corps could not be an active corps of engineers. Such experience is largely afforded by our so-called civil work which is, in effect, extra-military work for the American army engineer.

Since the early days of our young nation's history, her army engineers have been charged with planning improvements of and protection for her coastal harbors. Their respon-

— All Illustrations Courtesy The Military Engineer.

Ship entering Biscayne Bay.

Madden Dam and Power House — The last control struction for the Chagres in Panama.

sibility has been extended up the tributary waterways, including the Great Lakes, whereon has been developed the world's most efficient waterway system. In close connection with these navigation projects have come flood control, power development, and other water resource duties.

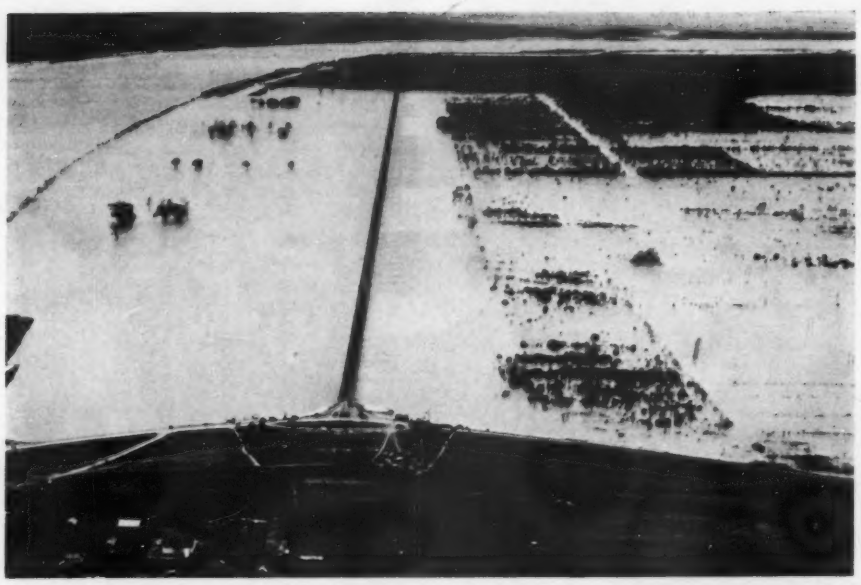
To cover the country's several hundred active Federal waterway projects and surveys, our Chief of Engineers under the Secretary of War in Washington has ten Division Engineers as immediate field subordinates. Each Division is composed of three or more Districts, of which there are forty-odd, in all, covering the United States, with each district covering a definite interior watershed or series of watersheds along the coast. Your able Colonel A. K. B. Lyman's Boston District comprises all of New England's watersheds tributary to the Atlantic Coast from Canada exclusive to Cape Cod inclusive. The Philadelphia District includes the Delaware watershed and the adjacent Atlantic coast. These two, with the three intermediate Districts of New York, Binghamton (for flood control), and Providence, comprise the North Atlantic Division with headquarters in New York City, under Colonel E. L. Daley, our youngest Division Engineer.

About half of our regular engineer officers are engaged on this river, harbor, and flood control work, as division or district engineers, or as assistants. Over ninety percent of the district personnel, however, is Civil Service of the highest type. These civilian engineers and administrative assistants are career men and women of proven ability and unswerving loyalty. They assure continuity, while their commissioned associates are changed on an average of every four years or less. These changes not only broaden and give experience, but provide a more national viewpoint as officers quality, for wider responsibility. It is probably the faithful adherence to such a national viewpoint, without local bias or political favor, that has deepened and held the confidence of the Congress. Army Engineer reports on proposed projects number in the hundreds each year, a large proportion finding Federal participation inadvisable "at the present time". As a rule, the Congress accepts such findings, pro or con, without question.

Here, in and about Boston, are several interesting samples of our peacetime work. Visiting engineers are being shown the model test study built and operated by the Civil Engineering Department of Technology to determine for your local Army Engineers their working predictions of tidal currents in the enlarged Cape Cod Canal, and the locus of its plane of mean low water. For our Chesapeake-Delaware Canal studies, we had conducted model tests in the U. S. Waterways Experiment Station at Vicksburg, Mississippi, to aid in the design of jetties at the Delaware River end of the Canal.

As one motors to Cape Cod or journeys through by train, one crosses the new bridges designed and built under the direction of Boston's District Engineer. The Bourne highway bridge was awarded the National Prize of the Steel Institute in 1935. From the canal bridges or their connecting roads, one may see the contractors' dredges deepening the canal to 32 feet, and also the novel bank paving "in the dry", preparing for an eventual width of more than 500 feet. This waterway will doubtless be deepened to 35 or even 40 feet to connect Boston's 40-ft. harbor channels with those of Long Island and New York.

As one passes Quincy, there may be seen the new dredger *Goethals*, being completed by the Bethlehem Company for Army Engineer service. It is the largest hopper dredge ever launched, having a hold capacity of 5,000 cubic yards. This modern turbo-electrically driven ship will improve and maintain the deeper coastal harbors of Boston, New York, and Philadelphia. It is perhaps appropriate to recall that Major George W. Goethals was selected to take over and complete the Panama Canal not only because of his recognized ability as an administrator and constructing engineer, but as a fortification expert. He was on the General Staff when he made the preliminary defense plans and accompanied the Secretary of War to the Canal Zone. Thus, the dual function of the Army Engineer was recognized and was justified. Under his administration as chief engineer and governor, General Goethals completed the Canal well within his cost estimates, even including the necessary fortifications.



The Lower Mississippi Excess Flood Waters flowing for the first time through the Bonnet Carre Floodway above New Orleans, 1937.

Down in Panama, floods in the Chagres are a menacing problem, and yet the storage of such water is valuable to navigation and to the development of hydroelectric power. The Chagres is now controlled by the Gatun, Pedro Miguel, and Madden dams. Similarly, one finds interrelated problems on New England's rivers, and, to a greater extent, on our Western streams. Flood control and power development plans are in the process of development on the Connecticut as well as on the Merrimac Rivers. There, as is often the case, the legal problems and rights of way present difficulties greater than engineering design and construction.

For the great Fort Peck project there was no delay, because the rights of way were secured by the United States, and not by the local interests, as required under the Flood Control Act of 1936. For this huge Montana reservoir, with the largest earthen dam ever attempted, the major purpose is water storage for Missouri River navigation and eventually for power. Imposing as this vast undertaking is, there are many features other than mere size to intrigue an engineer. It provides a characteristic example of the recent emergency responsibilities entrusted to the Army Engineers.

Authorized by the President in October, 1933, the Fort Peck dam site was being cleared within ten days, and by the following April a complete town had been constructed nearby, a thirty mile rail connection completed, the dam foundation stripped, a dredge boat yard opened, and all construction plans formulated — work affording employment for over seven thousand men. The Army Engineer put in charge of the new Fort Peck District moved from the humid lower Mississippi to frigid Montana in November, taking with him a nucleus of expert engineers, dredge builders, and other assistants to organize the relief personnel that had to be employed. Major Larkin had, in his young twenties, driven similar work to completion in France — readers should be permitted to read his own story — an epic in modern construction. In less than four years, that carefully co-ordinated program has diverted the entire Missouri flow through four thirty-two foot tunnels bored more than a mile through the hills forming the right abutment. The contractors failed to tunnel through treacherous shale and line it securely. But as he quit, the Army Engineer organization relieved his workers like troops in the front line. There was no pause in the work, as it simply had to be and was completed on schedule. When the closure of the river had to be made, the tunnels were open for service, albeit with less than a day to spare.

On further West across the continental divide, in the Columbia basin, was similarly authorized the Bonneville power and navigation project. The Columbia is tidal for the hundred and forty odd miles to Bonneville, where a ship lock is being built as part of the dam that will back the river, with over 30-foot depths, as far as the Dalles. The lift will be 66 feet, the highest of any lock yet built.

The concrete dam at Bonneville will be able to pass a million six hundred thousand feet per second, nearly forty percent more than the highest flood of record. The ultimate power installation will be nearly 450,000 kilowatts, although less than 100,000 are being provided at this time. The electric generators will each have a rating of 43,200 kilowatts, 13,800 volts, 3 phase, 60 cycles, with a power factor of 0.9 at 75 r.p.m.

Since the spawning grounds for salmon, trout, and other migratory fish are in the Columbia's headwaters, careful provision must be made at Bonneville to pass the large spawning fish upstream, and the fingerlings subsequently downstream. A pair of locks with fish ladders, all costing more than three million dollars, are being provided to protect this ten million dollar salmon industry, and the so-called game fish as well. The river model, in the Portland District's Laboratory at Linnton, is characteristic of our modern practice.

While power is popularly regarded as the immediate prime purpose of Bonneville, informed navigation students realize that all interior ports are destined to prosper like Albany, Trenton, Houston and Sacramento, and so will the Dalles in due time. In general, the further inland freight can be floated, the greater the public benefit. Thus, Bonneville is destined to return large benefits for navigation, as well as for power development and flood control.

Another West Coast emergency project was for flood control in Los Angeles County of Southern California. About twenty million dollars were made available to construct ten debris basins and dams at the mouths of mountain canyons and to enlarge the Los Angeles River channel. General plans having been made under the Army Engineer national survey of water resources authorized in 1927 (House Document No. 308, 69th Congress, 2nd Session), our local District Office was

(*Continued on page 160*)

Miami Seaplane Base.

Steels for Construction

A Survey of the Properties of the Alloy Steels

JOHN M. LESSELLS

SINCE man's upward progress from a state of barbarism has been due, in large part, to the metals he has been able to make available for his use, it is quite usual to define the various stages in such growth as the Bronze Age — Iron Age. We live in an age which is usually regarded as an electrical one, since it is customary to assess a particular country's industrial development today by the number of kilowatts of electrical power produced per head of population. In spite of this, however, ours must still be regarded as a Steel Age, since on this particular material depends in large degree not only the progress we have already made, but the rate of progress we will be able to maintain. It seems fitting, therefore, to review the various major developments which have taken place in the use of iron and steel since the beginning of historical time, and to add some remarks on more modern achievements.

The most ancient method for the extraction of iron from its ores and adapting this to the use of man originated in Asia, and India was probably the seat of this primitive process. When and where this became a possibility is lost in the mists of time for the faculty of doing things certainly was antecedent to that of recording them. The Hindus have always been notable workers in iron, and the simple smelting process used originally by them has been in use for several thousand years.

The ore and charcoal are put in through the top of the furnace and the fire continued for several hours. The pasty iron is subsequently lifted out through the top and hammered to remove part of the cinder. Such lumps of iron, weighing from five to thirty pounds, are still made by such primitive processes. The Hindus have also a primitive method of converting iron into steel by melting small charges of iron mixed with wood and leaves, and thus produced excellent steel from which weapons were made.

The Assyrians and Egyptians obtained their iron from India, and by them the art was transferred to the Greeks and Romans.

Water falling from the top reservoir to the bottom carries air which is forced through the blast pipe into the hearth. In actual working, charcoal is first thrown into the hearth and iron ore is introduced. The blast is then partially turned on by regulating a valve. In two hours, the hearth is in full blast and after about four hours the reduction is complete. The blooms, which weigh about 300 pounds, are broken up and taken to the hammer to squeeze as much of the slag out as is possible. Much of the iron used by the Spaniards at the zenith of their power came from this source. In Africa the same primitive methods are mentioned by Bell and Bellamy.

As regards the developments in Britain we know that the early Britons who opposed the Romans some two thousand years ago were supplied with iron weapons. The Romans further developed this method and erected a large forge for military purposes at Bath. The presence of cinder on the banks of several streams in England indicates that water power was used for the production of the blast and for forging. Developments must, however, have been slow, for as late as the time of Edward III iron utensils in the kitchen were classed among the royal jewels.

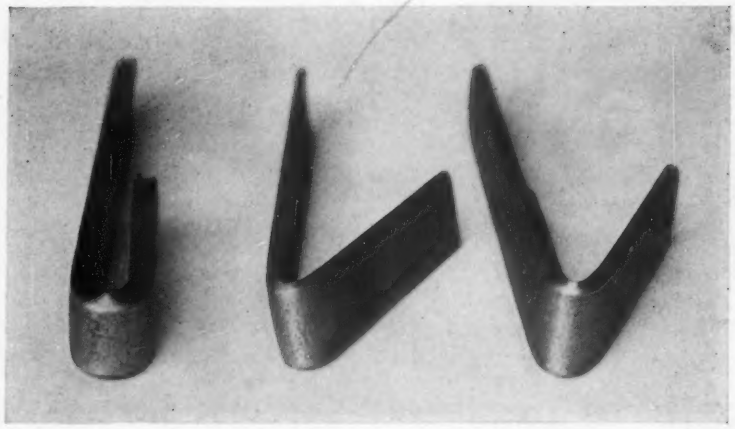
The melting point of pure iron is in the neighborhood of 1600° C., which was above the temperatures obtainable in any of the processes so far discussed. In the application of these primitive processes we can imagine a charge absorbing more than the usual amount of carbon, and running from the furnace in a liquid condition instead of being removed as the customary pasty mass. This is supposed to be the origin of cast iron, and the date is usually fixed as 1350 A.D., and the locale as Germany. In 1500 A.D. it was introduced into Britain when furnaces began to appear in districts where a plentiful supply of wood was obtainable. The development of the use of coke in the reduction of ore was the next step which led also to the blast furnace. By 1740, there were sixty blast furnaces at work and these had increased to 100 by the close of the century. It is interesting that a charcoal furnace was in use in the Ulverstone district of Scotland until as late as 1894. The production of iron by these processes was no more than ten tons per week for a charcoal and fifteen tons per week for a coke furnace. This marks the end of the Iron Age. The ushering in of the modern Steel Age had to await other developments, particularly that of the steam engine.

About 1730, Crowley in England introduced the manufacture of sheer steel. This process involved the packing of bars of iron with charcoal and heating these in a furnace for several days. The bar so obtained was called a "converted bar," and the amount of carbon could be controlled by time of heating in the furnace. This bar was made into shear steel by hammering down into plates which were then piled together, heated to a welding heat, and hammered together. This gave single shear steel. Further extension of this process was applied to give double shear steel for cutlery purposes.

In the upward progressive movement one of the most important developments was that of Huntsman, a clockmaker, who developed the idea that he could obtain a better product by melting broken pieces of blister steel in clay crucibles and pouring the melt into cast iron molds. This is of some interest because even today the development of new steels is largely brought about by the user rather than the maker. The Steel Age was, however, not really ushered in until the development of the Bessemer process in 1856 and the Siemens-Martin process very shortly afterwards, in which large quantities of steel can be produced at lower prices. The steam engine with the power blast contributed largely to make these processes possible. The subsequent developments in metallurgical knowledge, including that of steel making, have been international in character and are associated with such names as Sorby, Martens, Le Chatelier, Osmond, Howe, Sauveur, and many others.

In designing particular machine or structural parts where stress is the determining factor, the working stress is usually based on certain values of the physical properties of the particular material used. The chief tests employed by engineers are the tensile, hardness, fatigue, and impact tests.

The tensile test results are among the most important for the designer largely because of the vast amount of knowledge which has accumulated around these tests. Today, the choice of working stresses is divided into two parts, the first of which concerns static loads and the second of which deals with changing or cyclic loads. It is proposed that the working stress for static conditions be based on the yield point in tension rather than on the tensile strength, since the yield point marks the end of elastic extensions and the beginning of larger and permanent deformations. For those conditions where the loads are cyclic, the fatigue limit is recommended as the basis of working stress choice. There is no space here, however, to discuss these developments, so only a brief reference to the



Is Steel, Treated to High Strength, Brittle? Specimen strips, cut longitudinally from chrome-molybdenum (X-4130) tubing, bent cold. The tubing developed 200,000 psi. ultimate strength and slightly over 180,000 psi. yield strength.

tensile test interpretation will be made.

It is well known that increased yield point and tensile strength of steel is obtained by simply increasing the carbon content. Increase in carbon content, however, while it increases these properties, lowers the extent to which the material will deform prior to fracture. This deformation, measured by elongation and reduction of area, is of great importance in allowing machine parts to carry, for short periods of time, higher loads than those for which these parts were designed. These properties are known as the ductility of the material. Increases in carbon content increase, therefore, the strength properties such as the yield point and tensile strength, but lowers the ductility values as represented by the elongation and reduction of area; consequently, a limit is reached beyond which it would be unsafe to obtain an increase in the strength properties by a mere increase in carbon content alone.

This is shown by results given in Table 1 for carbon steels, which shows that as the carbon content is increased, then strength increases but the ductility decreases.

TABLE I

Carbon Content	*Yield Point*	*Tensile Strength*	*Elongation*	*Reduction of Area*
%	*lbs/in²*	*lbs/in²*	*%*	*%*
0.06	29,000	47,000	46	75
0.21	38,000	56,000	42	68
0.60	54,000	94,000	20	40
0.89	56,000	117,000	13	15

The next step to obtain an increased strength is by heat-treatment. Some data showing these improvements are given in Table 2 for 0.37 carbon steel.

TABLE II

State	*Yield Point*	*Tensile Strength*	*Elongation*	*Reduction of Area*
	lbs/in²	*lbs/in²*	*%*	*%*
Normalized	41,000	80,000	29	46
Quenched from 850° C.				
Tempered at 550° C.	69,000	105,000	22	56

The limitation of these methods for obtaining improved properties by heat treatment is that the mass effect, which precludes these benefits is obtained in very heavy sections. For instance, Aitchison refers to tests made from the center and edge of a 2-inch diameter bar of 0.85% carbon steel quenched from 850° C. The tests from near to the edge gave a tensile strength of 200,000 lbs/in² while at the center only a strength of 125,000 was obtained. Accordingly, improved properties are usually obtained by the use of alloying elements, the more common of which are nickel, chromium, molybdenum, vanadium, or a combination of these. The advantages of adding nickel to a carbon steel is shown in Table 3 which shows results obtained for a steel containing 3½% nickel and 0.35% carbon for the normalized condition. These results should be compared with

TABLE III

State	*Yield Point*	*Tensile Strength*	*Elongation*	*Reduction of Area*
	lbs/in²	*lbs/in²*	*%*	*%*
Normalized	60,000	104,000	22	49

those given in Table II for a normalized steel of similar carbon content with no alloying element to emphasize the improvements obtained by the use of these alloys. What is true for nickel is also true for the addition of the other elements mentioned. Additional advantages can also be obtained by heat-treatment of such alloy steels.

The above discussion explains, therefore, how improved tensile properties are obtained. First, by increase in carbon content; second, by heat-treatment; and third, by the use of alloys. What is true for increase in tensile properties is also true for other properties such as fatigue, since we know there is a more or less approximate relation between the tensile and fatigue strengths.

As regards the applications of steels to service conditions, it would be impossible in this article to give more than a few general statements.

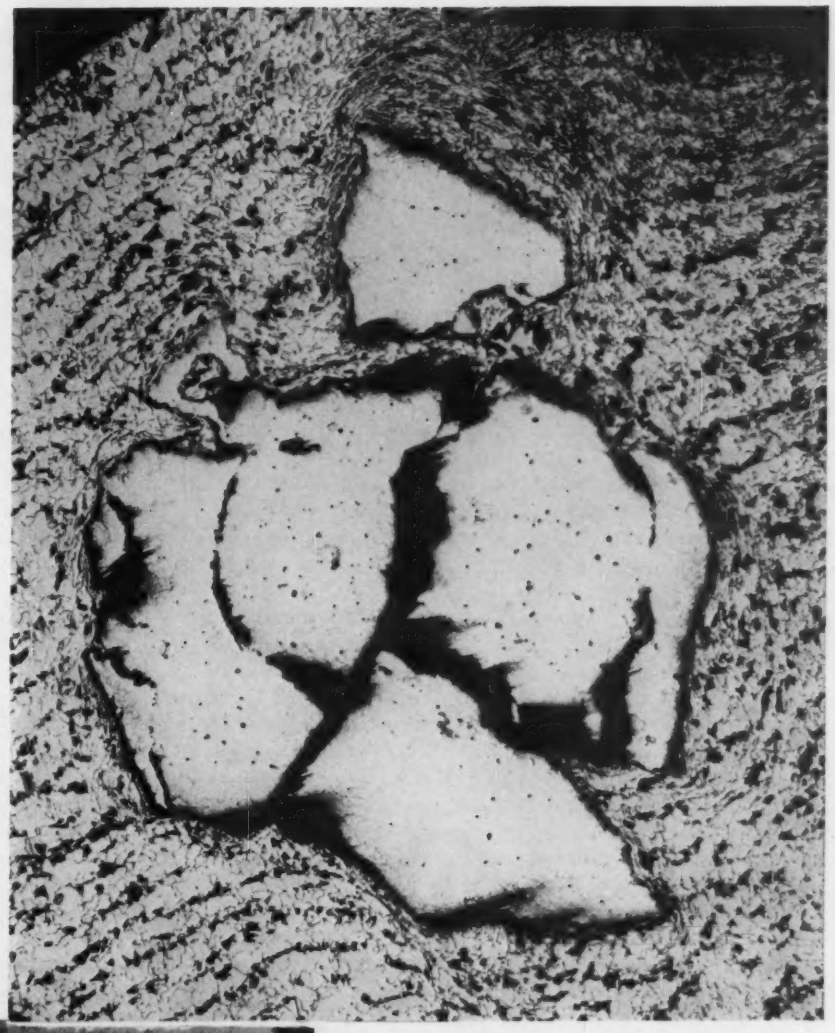
In 1740, the total production of pig iron and ferro alloys in Great Britain was 17,000 tons, while world production was 100,000 tons. In 1936, the world production had increased to well over 100,000,000 tons, or a thousand-fold increase in two hundred years. Progress has been much more rapid in the last hundred years because production has been accelerated by the development of the steam engine, which provided the power blast for obtaining the necessary high temperatures which modern processes demand. In spite of this development, nearly 80 percent of all steel made falls into the class known as plain carbon steels with a carbon content varying from 0.1 percent to 0.9 percent.

Carbon steels having a tensile strength of 65,000 to 70,000 lbs/in² in accordance with Lloyds' rules are widely used for marine propeller and marine engine crankshafts. Such steels are also widely used in steam locomotive parts and general constructural work, such as bridges. The use of alloy steels is, however, finding a place in the various constructions, especially in bridges, of which more mention will be made later.

The development of the internal combustion engine has enormously accelerated the use of alloy steels both as regards land and marine applications.

Alloy steels, especially those containing 1 percent to 5 percent nickel, are used in shipbuilding as well as the electrical, automobile, and aircraft industries. Steel of 1 percent nickel and 0.35 percent carbon is frequently used for bars and drop forgings for aircraft engines. Nickel 3 percent and carbon 0.15 percent is used for casehardening, and a similar steel of carbon content 0.25 percent to 0.35 percent is used where high strength without casehardening is required. Nickel steel of 5 percent with carbon content 0.10 percent is used for casehardening where higher strength is required over that obtainable for the steels of lower nickel contents. Steels of this type are frequently used in gears for automobile and aircraft engines. The 3 to 3½ percent nickel steels with carbon 0.25 to 0.45 are employed for reduction gear pinions for turbine driven vessels, and for large crankshafts for rolling mills and other heavy machinery.

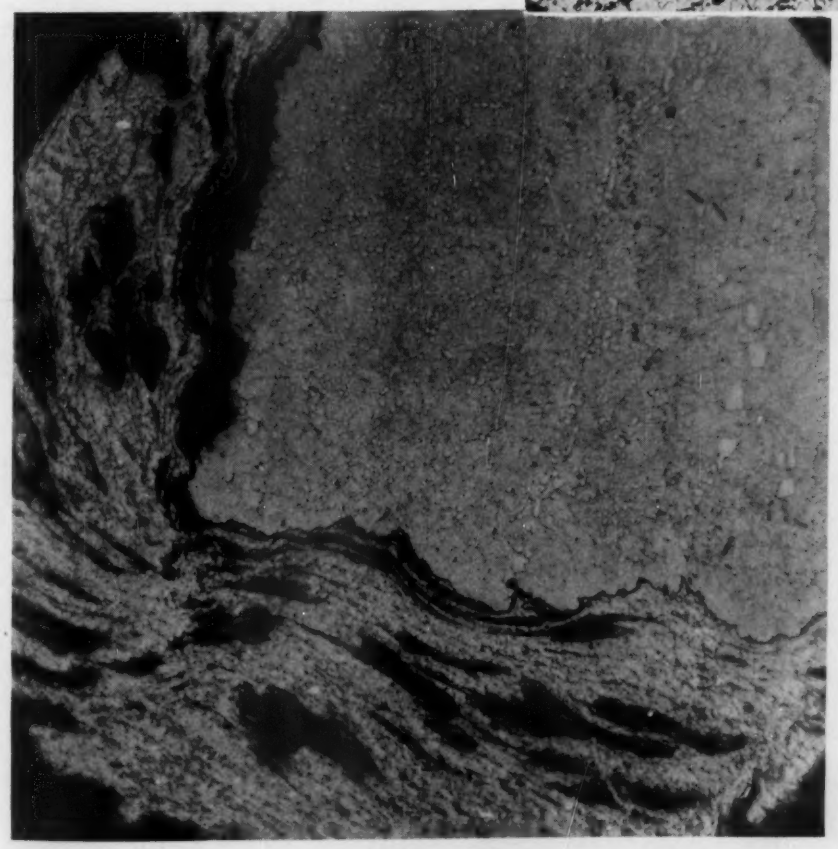
The nickel chrome steels of carbon 0.25 percent, nickel 3.25



A section just below the surface of a partly machined gear of S.A.E. 3120 steel, with imbedded foreign particles. Etched with nital to bring out the structure of the alloy steel, and magnified 50 diameters.

percent, and chromium 0.65 percent are commonly used for the crankshafts and connecting rods of internal combustion engines, although their use is not exclusive, nickel and other alloy steels also being used. Connecting rod bolts on land and marine engines of this type are also usually made of these alloy steels if the stresses are higher than ordinary, since failure of such is usually a critical one.

For a more detailed description of steels as used in these high speed engine developments the reader is referred to the comparatively recent paper by Dr. Dorey or that by Mr. Hague for more general information.



The same sample was then etched more deeply to bring out the structure in the inclusion and it was clearly revealed as a fragment of a high speed cutter. Note the intensely cold-worked structure in the metal of the gear immediately surrounding this embedded fragment.

Certain nickel steels have special applications but these are not generally classed as constructional steels. One containing 36 percent nickel, known as Invar, has a very low coefficient of expansion and is used for clock pendulums or reference standards, the dimensions of which are required to be independent of atmospheric temperatures. Another steel of 78 percent nickel gives very high magnetic permeability and is employed widely in radio and submarine telegraph industries.

Molybdenum as an alloying element is, comparatively speaking, a new development and there is evidence that it gives certain desirable characteristics as regards impact resistance and creep resistance. In a paper, O'Neil describes the application of nickel-chromium-molybdenum and manganese-molydenum steels for locomotive connecting rods with very good results.

In the transition which has been recorded from the methods used by the ancients to the modern metallurgical science of today, the engineer has played a decided part, because in parallel with these metallurgical developments there has been an increased study on the part of the engineer of

(*Continued on page 166*)

Fire in the Sky

Pyrotechics Have Had An Exceedingly Interesting History

IRVING PESKOE

IN the "forties" of the nineteenth century, the American brig, *Independence*, lay becalmed off Firabader Point in the Island of Sumatra. Her captain, Decimus Forthridge, a resourceful Yankee, had laid in a large supply of fireworks during his voyage in the East Indies, and now he quietly fumed as he thought of his loss if the boat should arrive home later than the Fourth of July.

For some reason, no ammunition was available for swivels or muskets when in the mid-watch of the night, two war proas, deeply laden with armed Malays, were seen coming quickly up on the vessel's quarter. The cry of "All hands on deck to repel pirates" brought the crew up immediately, but without ammunition they all realized that the odds were greatly in favor of the Malays cutting their throats as a preliminary to plundering and scuttling the vessel. Yet even in their plight the crew laughed and jeered when the captain ranged them along the quarter rail with boarding pikes and empty muskets in hand to give the enemy the idea that they were ready for business. The captain then opened a box of fireworks and began to shoot at the pirates. If the crew laughed, the Malays did not, and when an occupant of one of the proas was struck by a rocket, both crafts rested oars and came no closer. Their strategy was soon apparent, for a third proa came up unobserved under the port quarter, and the first knowledge of its presence was obtained when its occupants attempted to board the vessel by the chains. To make matters worse, it was discovered that the paper wrappings of the fireworks in the box were on fire. While the crew with clubbed muskets and boarding pikes kept the Malays outside the rails, Captain Forthridge picked up the blazing box, carried it to the chains, and while the mate and sailors warded the spears and krises from him, dropped it into the proa. The box was blown to pieces the moment it struck, scattering the fireworks through the proa. With fiery serpants running round their bare legs and firecrackers snapping and jumping everywhere, the Malays chose to take their chances with the sharks. As one man, all hands went overboard, forcing the other two proas to pick up from the water all that the sharks missed. While they were engaged at this, a little breeze came up, and the brig drew away from them with ease.

Fireworks have a long and romantic history. Since first mention of them is found in Chinese records, it is generally believed *that the Chinese were the inventors and first exploiters of pyrotechny*, the art of aerial fire. It must be remembered, though, that the primitive culture radiating from Egypt penetrated into China and often was the source of the latter country's developments. Most probably the Hindoos of India received their instructions concerning pyrotechny directly from Egypt. In this connection it may be said that, while the development of pyrotechny for purposes of spectacular display developed somewhat similarly in China and India, the Hindoos employed the art in contriving war weapons of a sort utterly unknown by their more peaceful neighbors.

These nations were never progressive. Oriental apathy has been demonstrated from time immemorial, and so we have the spectacle of Chinese mandarins and Indian rajahs placidly amusing themselves for several centuries with fireworks. How did they actually discover the principles behind them in the first place? According to one theory, a prehistoric firemaker mixed saltpetre from his cooking with charcoal from the fire, to use as tinder. The priesthood engaged in the study of substances which possessed an enormous tendency, under suitable conditions, to combine with oxygen with such violence as to yield products that were both hot and luminous to an intense degree. They did not know that an ordinary fire depends on the air for a sufficient supply of oxygen. They did, however, discover a few solid materials which contained oxygen so readily releasable that a combustion of extraordinary energy resulted. Later, the magicians pursued the inquiry into such phenomena, and have continued to study them, with varying fortunes, until today.

Avid for knowledge, the wise men of Greece took to themselves the old secret learning of the Egyptians, assimilated it, and made it their own. Some such learning, greatly expanded, resulted in Greek fire, a substance so highly combustible that it could not be extinguished by water. For four hundred years the Greeks jealously guarded all methods of preparing this combustible, for it was their most important weapon in time of war. Its discoverer was a student of alchemy, one Gallinicus of Heliopolis, a town in Syria. He prepared the fire by melting sulphur, resin, camphor, and other combustible materials, along with niter. Woolen cords were soaked in the resulting mass and afterward rolled into balls, ready for use. Thrown into ships of the enemy, or against their tents, these balls were practically inextinguishable.

The popularity of Greek fire remained constant until Berthold Schwartz, in the thirteenth century, evolved the principle of the gun and the name of gunpowder was derived. Against the new far-flung projectiles the fire was useless. Up to this time the Saracens were its most frequent users, employing it against the Crusaders. Very quickly the ancient fiery weapon vanished from the conflict — to return only after a lapse of centuries, in new guise, as a final horror of the World War.

The power that brought a new energy and glory to the art of aerial fire was that of the ancient civilization of Rome. The Latin race sought to dominate the world, and therefore took to itself every variety of luxury and art — everything that would make for a fuller life. The novel learning of the art of fire was carried homeward by the expeditionary forces in the Orient, and was immediately seized upon for the entertainment of emperor and populace alike. Exhibitions of fireworks, which included set pieces, were given in the Circus as early as the reign of the Emperor Augustus, and afterward during the reigns of Carinus and Diocletian. One of the more elaborate displays so excited the admiration of a Latin poet that he composed verses in celebration of it. From other writings of the age, we learn that it was customary to use, for the more imposing effects, a framework that was movable and fitted with adjustable parts, by means of which variously colored fires might be set into motion.

The overthrow of the empire in the west put a definite end to the Roman development of pyrotechny. The interval of inactivity began in the seventh century and continued for nearly five hundred years.

In the meantime, Greek fire, which has already been mentioned, was finding increased advocates. The Crusaders came in contact with it when they fought the Saracens, and by bitter experience gained an increased knowledge of combustibles, with which they returned to Europe. This started a growth of interest which resulted in the introduction of gunpowder and, somewhat less directly, in new findings in the art of aerial

fire. Thus was Greek fire reduced from a powerful war-time weapon to a mere curiosity.

Italy was the leader among nations so far as the cultivation of pyrotechny was adopted. During a period of a full century or more, holy days of the church were distinguished by vivid presentations in flame of some sacred story, appropriate to the saint it was supposed to honor.

For some reason not wholly clear, the Italian enthusiasm for this type of religious entertainment waned. At the same time, a new impulse drove the study of this art to increased activity in Germany, and more especially in France and England. In the latter two countries the fifteenth century witnessed a remarkable growth of pyrotechny for scenic effects, and this activity continued and increased steadily during the centuries that followed.

The coming of gunpowder brought in its train a considerable interest as to the composition of various combustible materials. Soon the ordnance departments of the different countries took over the active work in pyrotechny, and, except for the research of modern commercial plants, are doing so to this very day. The ordnance departments of that day, however, never failed to offer to the public a gala spectacle of flame on all occasions of national rejoicing. These pyrotechnic productions everywhere enjoyed the approval of the court as well as of the people.

In Italy and the Continent classical myths — including romantic and fantastic tales wherein fear-inspiring beasts threatened to consume hero and heroine with fiery breath — were common subjects for the fireworker's skill. Naturally the results secured at the outset were weird and lamentably crude. In the course of time, however, an artistic sense developed, and this kept pace with the progress in the art of aerial fire.

The British always loved to choose national narratives of heroic exploits for their pageants. St. George and the Dragon was a constant delight. Boadicea, too, had her place as the central figure of material achievements pictured in flame. The French were particularly devoted to Greek mythology, while the favorite characters for presentation by the pyrotechnists of Liege and Antwerp were those giants of Flemish legend whose grotesque effigies are still carried in procession through the towns of Belgium. In many instances on the Continent there was a clever intermingling of pagan stories and Christian doctrines, by which the fables of the ancients were diverted into allegories to illustrate church teachings, and were thus set forth as fiery spectacles for the entertainment and instruction of the people.

We can be concerned here with only that part of pyrotechny that deals with spectacular entertainment. Hence we must ignore the development of military weapons such as the rocket, the murdering marron, the carcasse, and the pyrophore. All of these machines were employed to start fire among the enemy's supplies. This type of weapon has changed too quickly to be important, and it will continue to change with each succeeding war.

By the seventeenth century military fireworkers were the only ones from whom any type of fireworks could be obtained. Since the governments of the various countries limited their displays to occasions for national rejoicing, such as royal marriages or state triumphs during war, the zest of the populace for entertainment with fire was left unsatisfied for great intervals of time. Realizing this, private enterprise jumped in and began to exploit pyrotechny. Resorts and tea gardens, to which admission was charged, began offering fireworks for entertainment. The immediate popularity of these resorts soon led to the private manufacture of fireworks, but, as yet, there was no public demand of them for home consumption.

Where did the firework industry stand at this time? We find that modern pyrotechny had only begun with the discovery by Berthollet in 1788 of potassium chlorate. Previous to this, saltpetre (KNO_3) had been the only salt used, and only a relatively few effects had been possible with it. Being a relatively stable substance, it did not give off its oxygen readily enough to provide startling reactions, and it could produce only tints of reddish and greenish colors. For these reasons, the entertainments before the middle of the eighteenth century would only succeed in boring an adult of today. Actually it was not until aluminum (in 1894) and magnesium (in 1865) were introduced into pyrotechnic compounds that a fraction of the possible color arrangements were secured. With these two metals and potassium chlorate, an entirely new brilliance was attained.

Several men have contributed materially to the field of pyrotechny. Ruggieri in 1812; Chertier in 1854; Kentish in 1878; and Antoni in 1893 all discovered improved means of making fireworks. It was the English resorts, chiefly Wauxhall and Ranelagh, that employed these men and others of their calibre. Their minds were a combination of the engineer's and the artist's, and they had the courage of the born daredevil. When the famous displays were instituted at Chrystal Palace in 1865, scores of professional pyrotechnists were hired, and later proved a great factor in the development of the modern display.

Meanwhile the United States was importing its fireworks both from Europe and the Orient. About ten years after the close of the Civil War, the most famous pyrotechnic displays in the whole country were being given on Boston Common on the Fourth of July. Any country boy who was so lucky as to see that display, with the miracle of George Washington's benign face illuminated amid sprouting flames and a shower of fireballs and rockets, had something to talk about the rest of the year.

Shortly after this period, an extensive manufacture of fireworks began in this country, with New York as the headquarters of the principal firms engaged in this business. Soon many peacetime uses of rockets and flares were perfected. Today, they are an especially valuable part of the equipment of ships that do not carry radio. Besides signalling distress at sea, a certain type of rocket can also carry a light line with which it establishes communication between a vessel and the shore.

Today motion-picture war scenes depend on fireworks for the smoke and flash of exploding shells and mines. Fireworks even supply the whine of bullets, since burning picrate emits a whistle that sounds like the noise of a passing missile. Practically all battle scenes, as well as encounters between fleets, are photographed in miniature, and a few handfuls of fireworks are enough to create scenes of devastation.

Pyrotechnic engineers use strontium salts for red fire, barium compounds for green, sodium compounds for yellow, copper compounds for blue, and magnesium salts for white fire. Iron and steel filings provide the glowing sparks. Practically all glowing fireworks are made from the same materials, the difference in effects resulting from the portions in which the chemicals are mixed. The engineer also uses a very modern development, electricity by name, both for firing off displays and for advertising purposes. Technically speaking, the neon light that everywhere blazons the world, is classified as a phase of pyrotechny. Perhaps when artists realize the possibilities in neon lighting we shall have a new source of beauty to delight city dwellers.

The future history of aerial fire seems dependent upon future military crises, for all important advances in this art since the close of the nineteenth century have been made by the ordnance departments of the leading nations of the world. Of value commercially are the increasing numbers of flares which are being perfected by the United States' pyrotechnic schools. These flares will be continually used whenever conditions render the usual lights dangerously dim or invisible.

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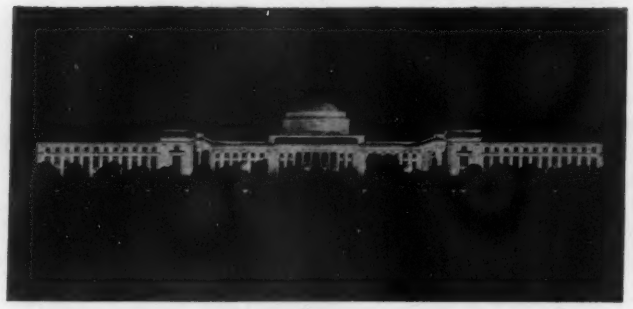


EDITORIALS

RESPONSIBILITY OF LABOR

THE recent sit-down strike in an anthracite coal mine at Coaldale, Pennsylvania, again has brought the question of responsibility of labor to the fore. Here, the miners, in complete disregard of the contract made by their own organization, the United Mine Workers of America, refused to work and remained in the pit for seven days, before coming to the surface. This incident along with other incidents which have occurred during the past year lead to the conclusion that a large part of labor and its organization believe in the sanctity of contracts until the opportunity of breaking them, advantageously, is presented.

Labor has made great advances during the last five years. The numbers of workers who today are organized is greater than ever before. Organized labor has obtained a degree of respectability and recognition it never before enjoyed. The power of organized labor is tremendous; it has so displayed its power to employers and marshalled public opinion that today the exception, rather than the rule, is for employers to try to resist the unions. Organized labor has impressed employers, as well as the public, with the responsibility of the employer towards labor. Laws designed to insure the good behavior of employers have been passed by both state and federal governments. Today capital is acutely aware of its responsibilities.

The reverse situation seems to occur in the unions, for they have constantly refused to recognize their responsibilities. Without doubt, in time this situation will cause a change in public opinion, which even now is beginning to cool. Such a change would force the unions to become responsible, for besides the employers the general public suffers from labor's lack of responsibility.

It might seem that the logical solution would be to force responsibility upon the unions by legislation as it has been forced upon employers.

Unions should be made to incorporate; severe fines should be imposed upon workers who strike in violation of established contracts. There should be an impartial labor board which would settle disputes before a strike even takes place.

Above all, the governments, state and federal, should be absolutely impartial and should stay out of disputes unless it appears that only by intervention can the public be protected.

WRONG ATTACK

IN Chicago's downtown loop area, where annually the dirt deposited out of the atmosphere averages a thousand tons per square mile, electrical engineers are artificially treating air to make it the cleanest in the world. Despite the fact that the

cleaning device is remedial rather than preventative, it is playing an increasingly important, although rather localized role in the fight against the smoke problem in industrial cities.

The apparatus, by a simplified process of electric precipitation, removes up to 99 percent by weight of all particles in the air being used to ventilate a Chicago office building. Since impurities of all sizes are drawn out of the air, the new device represents a great advance over mechanical filters, through which pass particles so small that they are visible only in sunbeams. In a year's time, the installation will have collected approximately 600 bushels of tiny particles, the greater part of which consist of ash, fixed carbon, and oils and greases. Sulfur, bacteria, pollen in season, and other substances are also deposited by the cleaner. As a method of ridding the air of bacteria, the electric cleaner was found to remove all but one micro-organism per liter of air.

The device has produced great reductions in household cleaning bills. It is being installed in one of the chemical laboratories of the Bureau of Standards, and is being considered for use in hospitals, automatic telephone exchanges, and art galleries.

Thus is provided the engineers' solution to the dirt problem inside city buildings.

But what is the point of equipping buildings with apparatus to keep the smoke out? Not every building and factory and home can be so benefitted. No matter how cheaply the apparatus can be operated, the expense for obtaining clean air rests upon the wrong person. It is absurd and unjust that one group of people should pay to keep their air clean, while another group freely pollutes the atmosphere with destructive and unhealthful smoke products. Moreover, such an air cleaner does not prevent the metal on building exteriors from being attacked and weakened. Nor is the pedestrian benefitted.

The correct engineering attack on the problem is rather to continue the development of treated fuels and of methods for obtaining complete combustion. The legislative attack, as we said last month, is to have cities enact laws requiring the use of these improved methods and fuels by everybody.

ANNOUNCEMENT

THE Managing Board takes pleasure in announcing the following changes in its personnel. Robert L. Johnson, '38, has been elected Business Manager to succeed Richard A. Novak, '38, who has taken a leave of absence from the Institute to continue his studies at the University of Brussels, Belgium. Will B. Jamison, '39, has been elected an Associate Editor, replacing R. Dixon Speas, '39, who is away from the Institute for the year, studying at the Boeing School of Aeronautics. Dixon has become a Contributing Editor. Samuel E. Hutchins, '39, has succeeded John C. H. Lee, Jr., '39, who is now a Cadet at the United States Military Academy, in the position of Publicity Manager.

"THE BOGEY THAT TECH IS HELL"

SELDOM in Technology's history has student enthusiasm been as evident as it was when the plans for the new gymnasium were announced. It is true, of course, that such enthusiasm has seldom been warranted: it is only once in a great while that some sport breaks a Technology tradition and produces a winning team. It is only at more infrequent intervals that plans such as the ten million dollar expansion program of a year ago are announced. There is, in fact, very little of the unusual occurring in the student life — very little outside of the monotonous classes, assignments, reports, and quizzes— very little of the extracurricular activity, both social and intellectual, that marks most of the other contemporary campuses. However, it is also a fact that few Technology students would want this missing glamour if it were to mean a sacrifice in the thoroughness of the education that they came here to receive.

This enthusiasm is, then, a fitting reaction to a well-conceived project and well-organized plan, a plan to build at Technology the athletic facilities that have been needed for so

(*Continued on page 168*)

North view of the proposed recreation center.

RESEARCH IN REVIEW

COURSE II — Heat Transfer

DURING the past winter, a study of the transfer of heat by radiation and convection across air spaces such as are found in frame construction, has been made by G. B. Wilkes and C. M. F. Peterson.

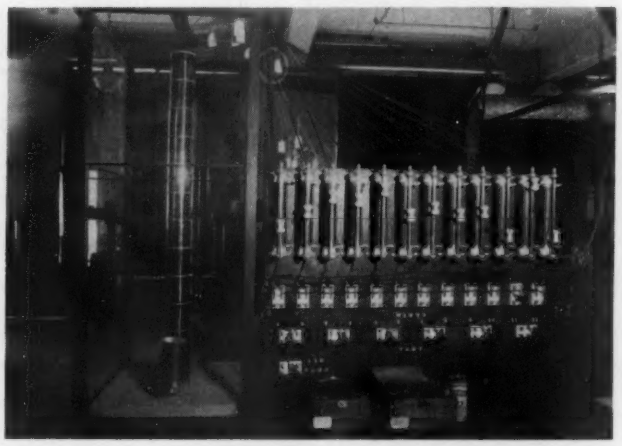
While considerable work has been completed along this line with ordinary surfaces in a vertical position and with small apparatus, little information has been available as to the effect of other positions such as horizontal or some intermediate angle with the heat flow either upward or downward.

Previously to the commercial development of the reflective type of insulation, air spaces were not generally considered very important factors in wall insulation. The effect of position upon the rate of heat transfer across air spaces faced with ordinary surfaces such as wood, plaster, paper, etc., while considerable, was not nearly as great as when the air spaces were faced with heat reflective surfaces such as metal foils, etc. In the first case, radiation is responsible for a large portion of the heat transfer — (radiation is responsible for about two-thirds of the total with vertical air spaces) — and is not affected by position. In the second case, radiation is largely eliminated and nearly all of the heat is transferred by natural convection. Convection is affected very materially by position as well as by the temperature difference and, furthermore, in this case, one has an air space that does play an important part in retarding heat flow through a wall.

For air spaces such as are usually found in buildings, eight or more feet high, it is not always safe to use coefficients determined on an apparatus with the air space only one foot in height.

With the above in view, it seemed of prime importance that more information be made available concerning air space insulation. Consequently, an apparatus with an air space eight feet high that could also be rotated to any desired angle was designed and constructed in the Heat Measurements Laboratory.

Under certain conditions, it was found that an air space may make an extremely effective insulator. For example, a horizontal air space with one side surfaced with a heat reflective material such as aluminum foil and with a difference in temperature of 20° F., was found to be equivalent in insulating value to one and two-thirds inches of corkboard if the heat were flowing downward. The same space under the same conditions except with the heat flow upward would be equivalent to about one-half inch of corkboard. The first case would correspond to conditions found with a flat roof exposed to a summer sun and the second case to the same roof under winter conditions with the heat flow upward. In a vertical position,



— Courtesy Heating, Piping and Air Conditioning.

Instruments for measuring heat flow.

— Courtesy Heating, Piping and Air Conditioning.

Apparatus for determining efficiency of wall insulation.

the insulating value of this type of air space was found to be equal to about 0.7 inches of corkboard.

Perhaps a more surprising way of showing the really remarkable insulating value of a horizontal air space, faced with one reflective surface, would be to use a single sheet of aluminum foil and subdivide the existing air space in a flat roof into two. With the heat flowing downward, this would be equivalent to adding about 3 inches of corkboard. The temperature drop across this double space is assumed to be 40° F., for this case but if the temperature drop were less, the insulating value would be even greater. Under winter conditions with the heat flow upward, this same piece of metal foil installed in the same manner would be equivalent in insulating value to approximately one inch of corkboard.

The importance of separating the heat transfer by radiation from that by convection in air spaces was brought out clearly in the investigation.

Heretofore, all data in regard to the insulating value of air spaces found in the usual handbooks and in the A.S.H. & V.E. "Guide", were based on vertical air spaces of relatively small size. The assumption is also usually made in these books that the rate of heat transfer across an air space is proportional to the temperature difference. This is not a fair assumption, particularly when the air space is faced with a reflective surface because then the heat transfer is largely by convection

which varies approximately with the 5/4 power of the temperature difference. In some cases, if these book values are applied to positions other than vertical and temperature differences other than those used in testing, it is possible that the true value may differ by more than 100 percent.

COURSE XIX — High Current Magnet

ABOUT two years ago, work was begun here at the Institute on a project to obtain intense magnetic fields in a form suitable for precise measurements. Instead of adopting the usual scheme of using very large iron core electromagnets, or reverting to Kapitza's methods of passing surges of current through a solenoid for one one-hundredth of a second, it was decided to develop water-cooled coils carrying very heavy current. This procedure made it possible to employ steady, homogeneous fields of great intensity covering amply large volumes for indefinite periods. The success of the enterprise depended entirely upon obtaining a suitable source of power

Dr. Bitter adjusting his 100,000 Gauss Magnet.

Through the courtesy of the Boston Edison Company, sufficient current was made available, together with space in one of their sub-stations for preliminary investigations. A small coil having about 160 turns was designed to carry 12,000 amperes, the heat generated by the 3000 kilowatts through the coil being disposed of by water flowing through it at the rate of 600 gallons per minute. The preliminary experiments indicated that this method was satisfactory, and it was decided, therefore, to install facilities for the operation of magnets of this type. Thus, it is now possible to carry on experiments involving both the new magnets and the other apparatus of the Institute.

A 1700-kilowatt generator producing a variable current up to 10,000 amperes is being installed next to the spectroscopy building, and three of the magnets are in process of construction. One will be used in the spectroscopy laboratory to give fields up to 100,000 gauss in a tube having an inside diameter of over one inch. A second will serve for low temperature work, producing fields of the order of 60,000 gauss. Finally, the original coil used at the Edison Company sub-station is being rebuilt to conform with the capacity of the new power plant. This third magnet will be utilized in a preliminary survey of the magnetic properties of certain types of alloys.

The chief purpose of the present installation may perhaps best be put in a few words by stating that it will make possible measurements that have not been previously attempted. What these measurements may reveal remains to be seen, of course. It is exploratory work, and no one can safely predict what will be discovered.

COURSE VIII — Van de Graaff Generator

A NEW housing for the Institute's large electrostatic high voltage generator is rapidly taking shape on Vassar St. The new arrangement of the generator structure is based on the results of a series of successful tests carried out at the M. I. T. field station at Round Hill, South Dartmouth, Mass.

The task of moving the generator from Round Hill to Cambridge involved problems in disassembly and reassembly because of the bulk and special nature of the spherical terminals and insulating columns. The spheres presented the greatest difficulty in actual transport, since they required 15 feet of road width and about 17 feet of height even though carried on a special low-slung trailer. It was necessary to raise wires all along the route from Mattapan to Vassar St. In addition to the 8 tons of generator structure, the moving included 26 tons of apparatus and equipment.

Construction of the generator at Round Hill was started 5 years ago by Dr. L. C. Van Atta under the supervision of Professor R. J. Van de Graaff and with the collaboration of Dr. C. M. Van Atta and Mr. D. L. Northrup. The project was undertaken as a result of the successful performance of a laboratory model developed by Professor Van de Graaff. Voltages greater than 5 million were obtained in about one year. Since

(*Continued on page 167*)

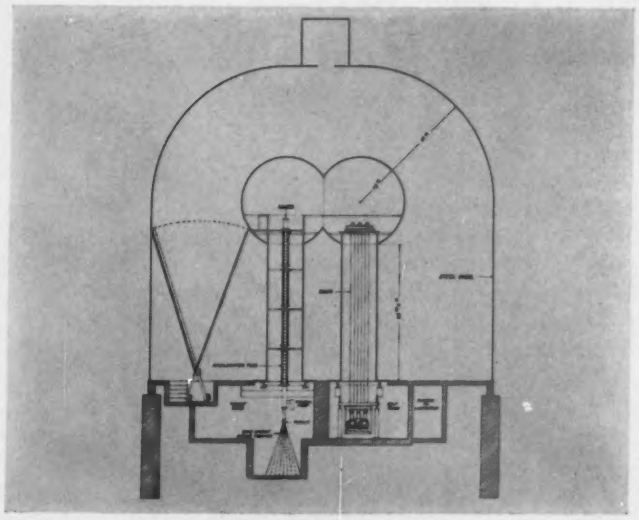
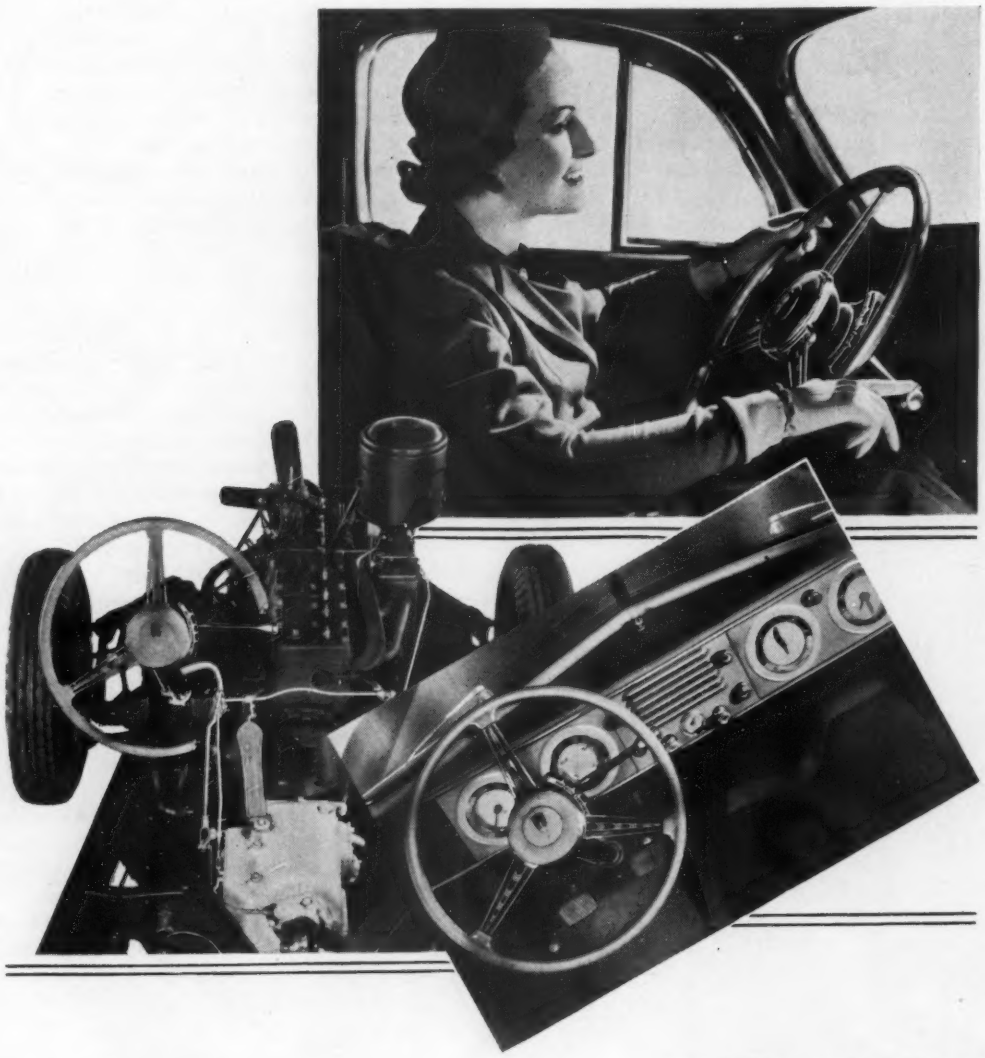


Diagram showing new arrangement of generator and equipment. Note that spheres have been brought into contact.

ENGINEERING DIGEST



NEW TRANSMISSION

FOUR forward gear speeds are provided in the new transmission which automatically operates through a mechanism controlled by oil pressure and engine speed. Embodying the idea of the "antiquated" Model T transmission, it consists essentially of two planetary gear sets placed one in front of the other, so that power from the engine may be transmitted through either or both gear sets. The automatic selection of the most efficient gear for each speed is controlled by a centrifugal governor incorporated into the transmission housing. The shift from one gear into another is accomplished through hydraulically operated pistons that control brake bands on the planetary gears and clutches within the planetary units. Thus, when the transmission is in low gear, brake bands on both gear sets are held tightly against the drums, transmitting the power through both gear sets. In second, gear only the rear planetary unit is contacted and power is transmitted through it. In third, the brake band of the rear unit is released, and the drive is through the forward gear set. In "super-drive", neither unit is in contact with the brake bands and power is directly transmitted from engine to driving axle. (Oil pressure for operating the hydraulic pistons on the gear sets is generated by a built-in pump). Shifting from low to the fourth high gear requires but one move of a control lever located on the steering column; otherwise, shifting is entirely automatic, and the use of a clutch is eliminated, except for starting the car. Moreover, shifting from high into the lower gears is easily accomplished in the planetary transmission, and this provides a safety factor for downgrade driving. Two other new features — a "super-drive" which permits the engine to work slower without reducing speed of the car, and a "pickup gear" which gives added power on hills and quick acceleration up to 65 M.P.H. — are provided in this new transmission, which engineers claim gives a 10 to 15 per cent increase in gasoline mileage.

— Popular Science

ELECTRIC SCOREBOARD

A NEW principle for driving the hands of scoreboard clocks makes them so accurate that they can be used for official timing of any game. The first installation, pioneered at Washington State College, consisted of a nine-foot clock in the basketball gym and a seventeen-foot clock on the football field. These two clocks utilize a new principle, whereby the power to operate the works is applied at the outer end of the second hand, instead of at the central axis of the dial.

The motive power is furnished by a 110 volt, 60 cycle synchronous motor geared to a connecting shaft installed under the large (second) hand. At the outer end of the shaft, the motive torque for the hand is applied through a pinion running on a circular rack. The hands are counterbalanced and are pulled around the periphery of the dial, making the accuracy very great and not affected by wind no matter how large the hand. Because of this patented principle, regular time indicators can be constructed as large as 150 feet across the face, which is three times as large as any clock now operating in the world, making them adaptable to unusual and spectacular layouts in connection with electrical display signs where extraordinary reader interest is desired.

— Electric World

ETHYL CELLULOSE

RECENTLY, the continuous search in the field of organic chemistry has resulted in the discovery of a new plastic, ethyl cellulose, for which dozens of uses have arisen. It was first prepared by Leuchs and Lilienfeld in 1912, by a treatment of cotton or wood cellulose with sodium hydroxide. The substance was then subjected to the action of an alkalizing agent, usually ethyl chloride, and was finally purified by distillation, re-crystalization, and simple washing.

The main virtues of ethyl cellulose are its flexibility, and its toughening action on oils, waxes, and resins. It is principally used as a thermoplastic adhesive for transparent wrapping material, and as a bodying material in heat transfers to textiles. Its widespread use has been retarded by the relatively high price of the raw materials which go into its composition.

Several of its physical properties are given below:

Melting Point	200–210 C
Softening Point	110–130 C
Specific Gravity	1.14
Breaking Strength of Film	400–600 kg per sq cm
Compression Molding Temp.	212-300 °F
Compression Molding Pressure	10000-5000 lb. per in.
Mold Shrinkage	.0003-0007 ins. psr in.
Tensile Strength	2000-7000 lbs. per sq. in.
Modulus of Elasticity	$2.8 \cdot 10^{-5}$ lbs,
Breakdown Voltage (60 cycles volts per mil)	1500
Dielectric Constant (10^3cycles)	3.72
Water Absorption (immersion 48 hrs.)	1.25
Burning Rate	— Slow
Effect of Age	— Slight
Effect of Sunlight	— Slight
Effect of Strong Acids	Decomposes
Effect of Weak Acids	— Slight
Effect of Strong Acids	— None
Machining Qualities	— Good
Clarity—Transparent, translucent, opaque	
Color Possibilites	— Unlimited

— Modern Plastics

BOULDER DAM GENERATORS

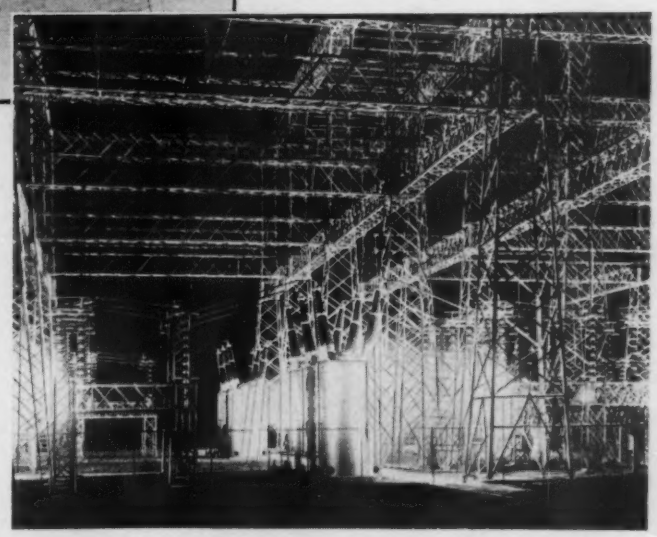
THE development of Boulder Dam as a vast store of natural energy has brought with it many tremendous problems in the transformation of this energy from water power to electricity. To help with the solution of the problem, four huge generators have been set up at the dam and are supplying Los Angeles with a steady flow of electric current.

The current is generated at 287,000 volts, and is sent across two hundred seventy miles of mountain and desert to the Los Angeles switching yard, where it is stepped down to 132,000 volts by seven 80,000 kilovolt-ampere transformers.

The demand for electricity is so great in the Los Angeles area, and the current can be transported across the large distances so much more easily at the high voltages used, that in time, the four 115,000 horse-power generators are gradually going to be increased to fifteen, and two 55,000 horse-power units will be added.

All these features, together with the dam, and man-made Lake Mead, will make this venture one of the largest, if not the largest attempt on the part of the human race to wrest from Nature the energy to supply the ever increasing needs of modern civilization.

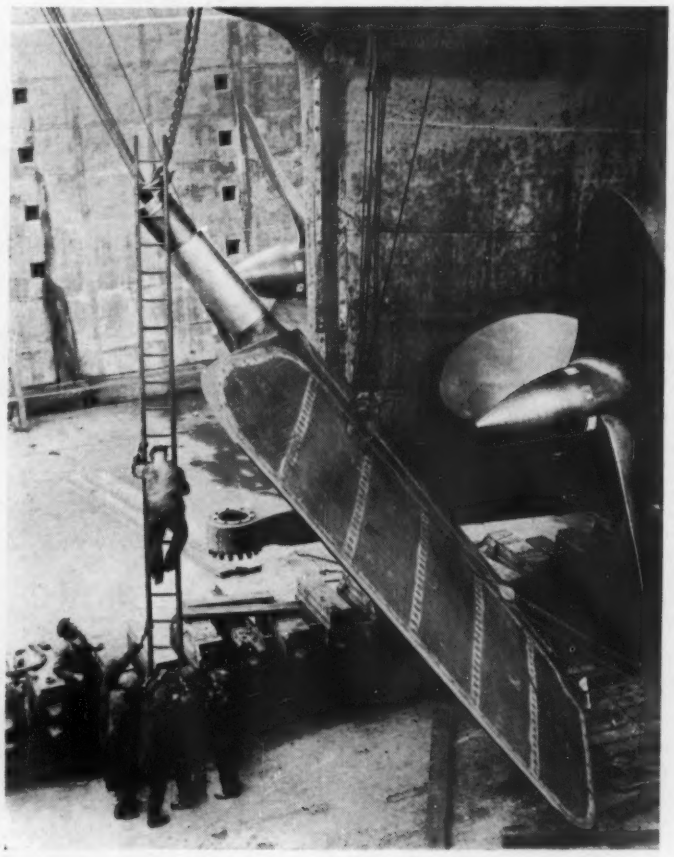
— Popular Mechanics



RUDDER ATTACHMENTS

A REMARKABLE example of the great difference between theory and practice in engineering is the case of the *Arundel Castle*, a 25,000-ton liner of the Union Castle Line.

It was found necessary to attach an eighteen-ton rudder to the ship, and when the job came up for action, the engineers found it was one thing to design, plan, and build an eighteen-ton rudder, but it was a far diffferent thing to attach one to a life size ship. The operation was merely assumed in the drafting room, but in actual practice, it required the close co-operation of mechanical engineers, experienced crane-operators, and dozens of men to make the thing fast. The operation itself is an extremely delicate one. The eighteen-ton piece of welded metal must be lowered slowly and carefully into position, and then must be jockeyed into place and the fittings must be attached immediately. The whole job must be done gently, and with a minimum of swing, as any undue swinging would necessarily result in serious and costly damage, and would undoubtedly throw all other operations off schedule, and in the end cost the company thousands of dollars. The knowledge, and watchful control of the various stresses and strains throughout the whole apparatus is essential, and the mechanical engineers spend long hours planning the whole thing out in advance, making the proper allowances for the safety factors, and finally formulating the plan of attack.



The rudder, which has been assembled and welded in the machine shop, is cautiously trundled on a heavy truck out to the drydock where it is to be fixed to the ship. At several strategic points on the rudder, wires and ropes are attached from the overhead cranes and the other block and tackle which are to be used in the course of the operation. Manned by experienced cranemen, the cranes raise the massive piece of metal slowly above the ground while a large ground crew directed by a corps of engineers watches to see that nothing goes amiss. The rudder is then carefully moved into place opposite the stern of the the ship, where it is made fast.

That theory and practice of engineering may be successfully linked together is exhibited by satisfactory completion of the case of the *Arundel Castle*, which now may be quite proud of her brand new rudder.

— *Popular Mechanics*

STILTED WORKSHOP

TRANSPACIFIC Clipper Planes of the Pan-American Airways are now serviced by a movable workshop at the company base at Alameda, California.

The workshop, standing twenty-one feet above the floor of the hangar, is mounted on wheeled stilts, and its two sections can easily be rolled into position to fit around the motors and fuselage. This arrangement facilitates servicing and enables mechanics to easily reach any part requiring attention.

— *Popular Mechanics*

NEW YORK SUBWAY

THE subway which is now being constructed under Sixth Avenue along Rockefeller Center's western front is the thorniest underground construction the city has ever undertaken. It is costing about $1,000,000 a block. At present, it is on schedule. It should be completed and ready for operation early in 1940.

Every type of tunnel digging is necessary over the two and a quarter mile stretch from 8th Street to 53rd Street — compressed air shield-driven, rock, and cut and cover tunneling. The subway must weave its way under and over the most intricate network of obstacles — natural and man-made — that subway engineers have ever faced. It must blast its way through the very vitals of midtown Manhattan,where an injury to any one of the myriad of pipes and ducts, the nerves on which the life of the city depends, could mean a major disaster.

Most futile of the many precautions is the propping up of the Sixth Avenue "L" while the subway tunnels are being blasted under it. This operation adds $5,000,000 to the cost, and when the subway is finished these props will be torn down! To hold up the structure each column must be riveted to steel girders a little above the street level. These, in turn, rest on criss-crossed steel beams and concrete piers.

If the buildings along the avenue do not rest on rock,they must be shored up on concrete walls which rest on bed rock, before blasting or excavation can be done.

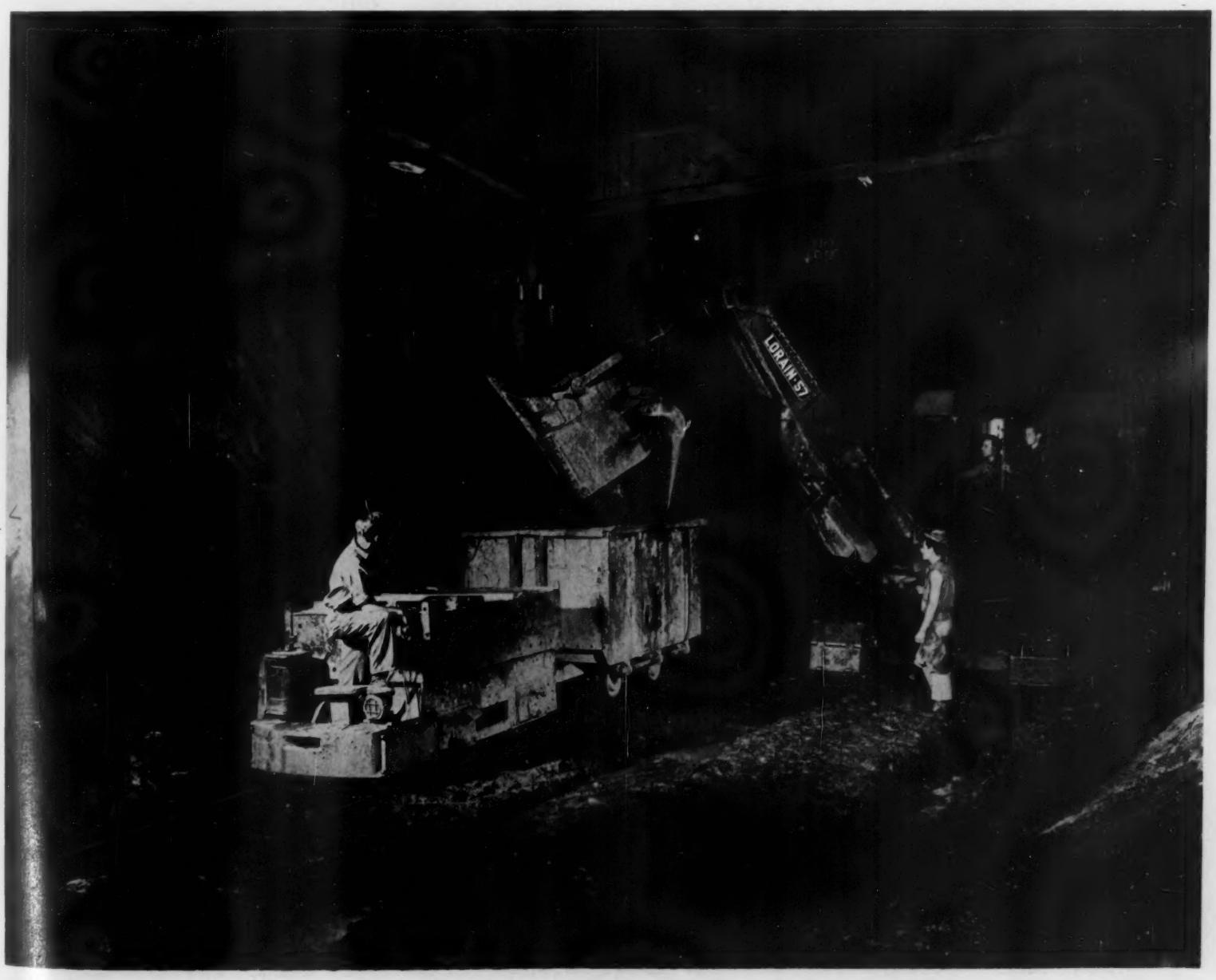
The accompanying illustration shows a portion of the subway under construction. Notice the shovel with its short arm, especially constructed to work in the necessarily cramped space of the subway tunnels.

No service can be cut off, so there is a complete system of temporary sewers, water mains, gas mains, and the like, all supported by steel cradles and hangers.

All the time the subway must follow, more or less, the up and down grades of the earth's surface to avoid unduly long stairways. The four-track tunnel now being bored in front of Rockefeller Center will be thirty-five feet below the surface.

The far-flung lines of the subway system, bringing their hundreds of thousands into midtown every day, will converge on the arcades, tunnels, and concourses which link the buildings of Rockefeller Center. Subway men estimate that in excess of 300,000 people will use this Rockefeller Center station every day.

— *Rockefeller Center Weekly*



THE U. S. ENGINEER CORPS

(*Continued from page 146*)

ready. Within two months after authorization, a staff of twelve had been expanded to over four hundred, initial construction plans and designs were prepared, and all project items were under way in the field. Within a year a peak employment of 16,400 had been reached with an average of 94 per cent from the relief rolls. In spite of the difficulties inherent in working relief labor, unit cost figures have been kept down under immediate Army Engineer supervision. This experience has been repeated on practically all of our own so-called relief jobs. It has been said that these jobs were made available in order to sustain the morale of the persons needing relief — in other words to retain the worker's self respect. That meant rendering a day's work for a day's wage. Our rule has been to expect and to realize just that. If a relief worker is found loafing, both he and his foreman are likely to be fired. Colonel Brehon Somervell's success in enforcing this policy in Florida was the forerunner of his being detailed as Works Administrator for Greater New York. He too, in his early twenties, had earned a brilliant reputation in France both on construction work and on the front line.

In San Francisco Bay, two remarkable bridges are nearing completion. All such structures over navigable waterways must be approved by the Secretary of War and the Chief of Engineers. These two bridges may have critical influence in defense plans — factors of Army interest in addition to these structures being abutted upon or crossing Federal reservations; i.e., the Presidio (Headquarters of the 9th Corps Area) and Yerba Buena Island. Adjacent to the latter, the site of San Francisco's new Exposition ground is being filled in. When this hydraulic fill project was advertised, the various prospective bidders went on record that the available funds were too small and the prospective risks too great. Army Engineer equipment was therefore assigned, and although extreme conditions of weather have been experienced, the work is progressing well within the time schedule and estimated funds. Such "hired-labor" operations not only save the Government heavy expenditures by holding contract prices within reason, but afford excellent actual experience for our junior engineers in responsible charge.

Probably the most severely punished of all our coastal structures are the North Pacific jetties — huge rock piers extending across the river bars into deep seawater, exposed to the violence of storm, wind, and wave. Even the heaviest cap stones that can be placed by powerful cranes are subject to later displacement by the pounding fury of storms. Our people have long sought an effective means of binding these mammoth stone structures together, and are now experimenting with an asphaltic concrete that has proven successful along the Gulf coast. There, our Army Engineers have carried from their lower Mississippi River bank revetment practice, the art of mixing hot asphalt with properly graded sand to form an effective binder.

Below Fort Peck on the Missouri River, it is expected to obtain working depths during the navigation season by confining the regulated flow in a properly restricted channel. Permeable dykes, of suitable length and in carefully predetermined position, check the heavy silt load carried by the stream in flood, and build up the banks something like the action of snow fences. The laboratory for such experiments is the Missouri itself.

Farther eastward on the upper Mississippi, there is insufficient low water flow to provide the needed navigation depths without canalization. Therefore, a series of locks and dams is being expedited as a result of the emergency program, each dam forming a slack water pool for commerce to reach by means of the locks. The dams must be capable of passing flood waters and ice. For these purposes, very large roller and tainter gates have been designed so as to clear high water stages above pool levels, and yet be able to drop eight feet below pool level to pass ice jams. Model studies have been extensively used in

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The waterfront at Miami, Florida.

THE U. S. ENGINEER CORPS

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the design of these and other lock and dam features.

The construction of these installations down in the river bed afford rare experience for young engineers. The work is carried on inside cofferdam enclosures to permit the close inspection of the foundation and actual construction in the dry. The steel sheet pile cellular type of coffer has replaced the wooden box of a decade ago. Dewatering practice has been improved by the use of well points, especially in permeable bottoms, rather than by means of ditches, sumps, and surface pumps. This avoids the placing of concrete in water and permits the realization of benefits through improved concrete mixing. On all of this work, accurate control of both aggregates and water is maintained by means of automatic devices regularly verified by laboratory tests. Vibration is used in placement and great care exercised to keep the concrete moist until fully set. By carrying into our field practice the latest theory of university laboratory, we are greatly reducing the uncertainties formerly inherent in concrete construction.

In the Ohio basin, the nearest of the Mississippi's three great tributaries, we are rebuilding the navigation system and constructing, as funds are made available, an extensive flood control system. The old movable navigation dams, of low lift to permit the open river passage of huge coal tows in high water, are being replaced, in some instances, by higher fixed dams.

On the Muskingum, the emergency program authorized a large number of earthen flood control dams. Army Engineer experience with the Gatun dam in Panama and the hundreds of miles of Mississippi levees has been considerably advanced by laboratory experiments and field practice in the Ohio Division, as well as at Fort Peck, in New England, and in the South. Dr. Karl Terzaghi's work at Technology has been followed, through the consultant assistance of Doctors Gilboy, Taylor, and Casagrande, and the employment of many Technology experts including Buchanan, Middlebrooks, Hough, Hartman, Hansen, and Philippe. Field laboratories for soil mechanics, hydraulics, or concrete are being operated by the Army Engineers at Vicksburg, Miss., Zanesville, Ohio, Memphis, Tenn., Fort Peck, Mont., Concord, N. H., Providence, R. I., Ithaca and West Point, N. Y., Little Rock, Ark., and more recently at Denison, Texas, Los Angeles, Calif. and

(*Continued on page 163*)

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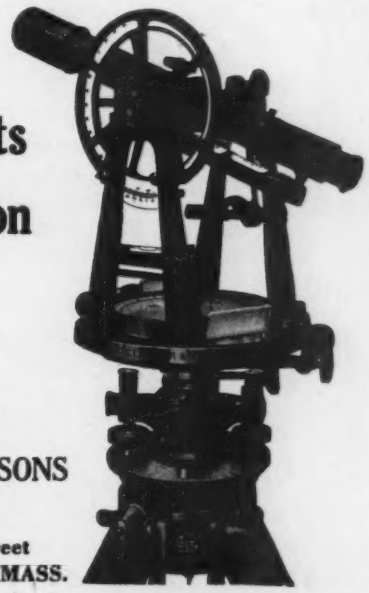

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NICKEL AND NICKEL ALLOY

(*Continued from page 143*)

to oxidation and deformation at temperatures of 1200–2300° F. Tungsten is sometimes added for superior creep resistance. The alloys generally contain 8 to 60 percent of nickel, 15 to 30 percent of chromium, with the balance iron. Many of these alloys are malleable. This property greatly extends their usefulness.

7. *Miscellaneous Group*

A. *Jewelry Alloys*

Many articles of jewelry contain appreciable amounts of nickel. Nickel is added to gold to produce "White Gold." Nickel, Monel, and Inconel are covered with gold and the composite section rolled for opticians' supplies as well as for jewelry articles. Gold-covered nickel wire finds extensive use in the dental industry.

B. *Manganese-Nickel Alloys*

These contain from 2 to 6 percent of manganese and have a definite use for electrical resistance purposes in the manufacture of special equipment. One percent of manganese increases the specific electrical resistance of nickel approximately 13 ohms per mil. foot. The 5 percent manganese-nickel alloy has good resistance to sulfurizing atmospheres at elevated temperatures and is used for spark plug wires and for fire-box stay bolts.

C. *Thermal Expansion Alloys*

A series of useful alloys has resulted from the peculiar thermal properties of nickel and iron. As the nickel content in these alloys exceeds 30 percent, expansion decreases rapidly and becomes almost nil at 36 percent. This alloy is known as Invar. Additions of chromium, molybdenum, and manganese to it have produced a special alloy having an invariable elastic modulus under ordinary temperature conditions. This alloy is used for springs in many precision instruments. The 46 percent nickel-iron alloy has practically the same coefficient of expansion as glass, and has largely replaced platinum for metal-to-glass seals.

These nickel-iron alloys do not compare favorably with nickel steels with respect to mechanical properties. Their corrosion-resisting properties are, however, superior except for Stainless Steel. Their mechanical properties at sub-zero temperatures are excellent and they, therefore, are used in the construction of commercial liquid-air plants.

It is not an exaggeration to state that nickel is a universal alloying element. Twenty-eight percent of the 8200 alloys listed in Woldman's and Dornblatt's "Engineering Alloys" contain one or more percent of nickel. Many others contain from 0.25 to 0.90 percent of nickel.

Nickel has the unique property of improving most alloys to which it is added. This improvement is usually in the direction of greater strength and toughness, better resistance to corrosion, better working properties, and specially desired physical constants. This is well illustrated by the data given in the accompanying tabulation.

It is equally true that nickel is essentially a peace-time element. The automotive industry now consumes the largest proportion of nickel. At least twice in recent years the supply of nickel has threatened to exceed the demand, only to find that the research activities of the nickel industry had been instrumental in discovering new and improved uses for the metal and its alloys which required capacity operation of all production facilities to meet industrial requirements.

The growth of the nickel industry is one of the outstanding triumphs of research in our mechanized age. Because better facilities for research are continually being provided, the future for nickel is brighter than at any time in its half century of industrial progress.

AVERAGE PROPERTIES OF NICKEL, NICKEL ALLOYS, AND OTHER IMPORTANT ALLOYS FOR ENGINEERING PURPOSES

		Approximate Chemical Composition						Average Mechanical Properties					
Alloy	*Condition*	*Ni.*	*Cu.*	*Fe.*	*Cr.*	*Mn.*	*Other Elements*	*Y.S. 0.00% set (psi)*	*Y.S. 0.20% set (psi)*	*T.S. (psi)*	*% Elong. in 2 inches*	*Brinell (3000 Kg)*	*Izod Impact ft.-lb.*
Nickel	Hot rolled	99.40	.10	.15		.20			25,000	75,000	40.0	130	100
Monel	Hot rolled	67.00	30.00	1.50		1.00		20,000	45,000	85,000	45.0	150	120
"K" Monel	Age-hardened	66.00	29.00	1.00		.25	2–4 Al.	90,000	110,000	150,000	20.0	300	50
Inconel	Hot rolled	79.50		6.50	13.00	.25		35,000	50,000	95,000	40.0	160	
Cupro-Nickel	Hard drawn	30.00	70.00						58,000	65,000	17.0	110	
Nickel-Silver	Hard drawn	18.00	65.00				18. Zn.		83,000	90,000	5.0		
Copper (OFHC)	Cold drawn 60%		99.99							60,000	10.0		
Brass (Admiralty)	Hard sheet		70.00				29. Zn. 1. Sn			95,000	5.0		
Aluminum	Hard sheet						99. Al. 1. var.		21,000	24,000	5.0		
Aluminum Bronze	Hard rods–H. T.		90.00				10. Al.		67,000	125,000	5.0		
Ni. Aluminum Bronze	Hard	4.00	92.00				4. Al.	60,000	90,000	120,000	3.0		
Stainless Steel	Hard	8.00		bal.	18.00			50,000	70,000	110,000	40.00	220	110
SAE 1035 Steel	Quenched and drawn 900° F.			bal.		.75	.35 C.	50,000	75,000	105,000	20.0	210	50
SAE 2330 Steel	Quenched and drawn 900° F.	3.50		bal.		.65	.30 C.	105,000	130,000	150,000	17.5	320	35
SAE 3330 Steel	Quenched and drawn 900° F.	3.50		bal.	1.50	.45	.30 C.	125,000	150,000	180,000	16.0	350	30
SAE 4340 Steel	Quenched and drawn 900° F.	1.75		bal.	.65	.65	.35 Mo. .40 C.	150,000	180,000	200,000	14.0	410	25
Creep Alloy Steel	Annealed	20.00		bal.	26.00		.15 C.			95,000			
Creep Alloy Steel	Annealed	11.00		bal.	23.00		.30 C. 3. W.			115,000			

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(*Continued from page 161*)

Eastport, Maine. The functions of these laboratories are three fold: (a) to make tests, experiments, and research necessary for the design of each project, (b) to continue tests needed to check actual construction, and (c) to train inspectors both in the practical theory behind the work they are to supervise and in the best methods to verify results on the job.

Army Engineer organization is kept flexible, and thus is able to expand in meeting new projects or emergencies, as well as to retrench in achieving economies. Districts and even Divisions have been opened up or closed by consolidation as needed. The Zanesville office is becoming a part of the Huntington District while the Tygart project remains as a sub-office of Pittsburgh.

Tygart River, one of the Ohio's headwaters, is a mountain stream with a large flow variation; i.e., a range from 58,000 to 1 cubic feet per second! Regulation will be of value in reducing flood heights at Pittsburgh and along the Ohio River. In the low-water season the stored water will be released to carry the heavy navigation on the Ohio and Monongahela systems. It is expected that the gravity section dam, 1,850 feet long, 230 feet high, and containing about 1,200,000 cubic yards of concrete, being built near Grafton, West Virginia, will effectively provide the desired regulation.

Early in 1937, the importance of all these flood and navigation projects was emphasized when the Lower Ohio built up a record flow, and the Mississippi delta from Cairo to the Gulf was saved from inundation by the successful functioning of General Jadwin's Army Engineer Plan.

In view of the general misinformation current about flood causes and cures, fearless fact-facing and straight thinking

(*Continued on page 164*)

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(*Continued from page 163*)

are needed. Floods are caused by excessive rainfall beyond the capacity of drainage to carry off the water. Such rains cannot be prevented, nor can all of such waters be restrained. In extraordinary deluges, it is common sense to help the excess waters flow down to the sea,lest they invade and destroy property and lives. Such conditions may be compared with traffic movements. Cities lying in the valleys of trade and travel provide arteries for such flow. To protect the residents and merchants against undesired interruption, walls and gates are provided, like the levees and walls of the river channel, increasing the protection. Where traffic develops in excess of the main artery's capacity, by-passes are the next logical improvement — lateral highways around the cities, or by-pass channels for flood waters. Only as a last resort does a city provide detention camps for hunger marchers, although the normal and highly desired volume of transient visitors is stored in hotels, tourist camps, and even in homes. So it is profitable with temporary water storage to store some, but very costly to provide emergency storage in great quantity. Such investments mount into large figures returning much less for the outlay than the simpler commonsense measures.

On the lower Mississippi, the Army Engineers have first improved and increased the carrying capacity of the main channel, straightening it where practicable, and paving it against too rapid wear and tear. Above bankful capacity an additional hundred percent passage has been afforded by the lateral levees built as high as foundations and reasonable safety justify. The next increment for excess flow is through by-passes or flood-ways such as at Birdspoint below Cairo and at Bonnet Carre above New Orleans — both effectively operated in February, 1937. Still further flood protection by reservoirs is planned to be provided as funds can be made available.

A conspicuous example of perfect flood control of a river by reservoir is the Saint Lawrence with her five Great Lakes. If the Mississippi, with three times the St. Lawrence average flow were to be similarly controlled, her fifteen great reservoirs would cover far too much valuable valley acreage. Army Engineer service on the Mississippi for more than a century has been useful not only in faithful fact-finding and fearless fact-facing for commonsense improvement but for emergency mobilization leadership and co-ordination during extraordinary flood crises. There, as in war, the time factor is vital.

Where the mighty Mississippi pours out into the Gulf, her alluvially formed delta outlets have been studied and guided to afford adequate navigation depths — an intriguing problem in practical hydraulics.

Around the Gulf Coast and along the Atlantic Seaboard is being opened an inside water route designated by the Congress as the Intracoastal Waterway. Florida has many projects in active status, notably Tampa and Panama City on the West coast, with Key West to the south, and Miami for sea planes and shipping, and Jacksonville's improved St. Johns River.

The South Atlantic ports of Savannah, Charleston, Moorhead City, and Wilmington, present the peculiar problems of drifting sands along low lying shores. There, and especially further north along the Virginia, Maryland, Delaware, and Jersey shores are found the conflicting interests of beach protection against erosion, and those for navigation jetties, or for other reasons to save heavy expenditure. The Army Engineers are studying these problems, seeking a reasonable and economical solution in the laboratory as well as along the storm swept sandy coasts. On the Engineer School reservation at Fort Belvoir, Virginia, the Beach Erosion Board has a model apparatus for wave action experiments. Plans are being formulated to enlarge this layout at Dalecarlia Reservoir, an element in the Army Engineer built and operated water supply system for the City of Washington.

At the Engineer School, also, is the testing laboratory and terrain for the Engineer Board to develop military engineer equipment, such as bridges, floating and fixed, searchlights, aerial mapping, camouflage, demolitions, field water supply, and all kinds of road building. These Boards,like the Board of Engineers for Rivers and Harbors for the review of all proposed River and Harbor and flood control projects, are conveniently held in or near the Office of the Chief of Engineers in the War Department. Thus, departmental contacts are assured, the policy determining headquarters being able to guide and yet not dominate these activities along the shores of Chesapeake Bay.

As one flies northeastward from Washington, leaving Chesapeake Bay and heading for the Delaware, one sees the widening strip of a century old barge canal now being made into a modern two-way ocean going ship canal. The old C. and D. Canal, completed in 1829 as a government-aided private enterprise, played a vital part in commercial and military history between Philadelphia and Baltimore. It cuts the connecting water route to one fourth — a full day's steaming for freighters and tankers. It became a Federal project in 1919, when we deepened it to sea level, rectified its alignment, and provided the necessary bridges. So heavy a commerce has developed, that we found economic justification for deepening the waterway to 27 feet with a bottom width of 250 feet. To accomplish the excavation plan and to straighten the extended bridges without interruption of either highway, railway,or waterway traffic has presented a problem worthy of our young Army Captain serving as resident engineer. This is but one of the continuing problems facing our resident engineer, who was detailed in charge of the engineer program work as soon as, or indeed in immediate anticipation of its authorization. To give him residence in fact, on the job, we built for him a prefabricated house of modern design, and expanded his field office to house the greatly enlarged staff.

While the heavy yardage moved on the canal project has totaled some thirty million in this District, such volumes are not far in excess of that moved annually from the main channel in the Delaware, between Philadelphia and the Sea, prior

(*Continued on page 165*)

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(*Continued from page 164*)

to the full functioning of Pea Patch and Reedy Island dykes. These structures guide the tidal currents practically parallel to and thus through rather than across the 800 by 35 foot dredged channel, and have reduced the maintenance yardage to approximately half. The mud we remove in hopper dredges is rehandled ashore by long pipeline equipment, thus conserving the material and building up low swampy land for industrial or other use. This 35 foot channel is up for review at the present time, since the local interests want a 40 foot port. One factor is the "squat" of heavily laden steamers when under way in confined channels. With the helpful co-operation of the shippers, we have made extensive observations of squat and find it may amount to between 2 and 3 feet under present operating conditions.

Another factor is the increase in draft experienced by vessels entering a fresh water port from the sea. To understand this factor adequately and to observe the intrusion of salinity as the channel to the sea is enlarged, we use special electrical equipment based upon the principle of conductivity by measuring automatically both electrical resistance and temperature of the water.

Another interesting automatic record is being obtained of the ocean currents off Absecon Inlet channel at Atlantic City, N. J. Here is a difficult problem of avoiding any damage to the delightful and highly valuable beaches while attempting to stabilize the navigation channel and afford storm protection to entering ships as they cross the bar. Foreign made Idrac current meters record the direction and velocity within the needed limits and for a week's period. With these data, the correlation of tide, wind, and ocean currents is obtained from automatic recording tide gauges and wind records. This, together with full hydrographic data, should provide sufficient information for model test experiments to determine the probable effect of low jetties in the channel and on the beaches.

For any such study involving tidal flow in estuaries we find the cubature method very useful. By adjusting the computed volumes, filling or emptying, above a given station the rate corrected for fresh water discharge can be derived. To avoid scour and silting, a fairly uniform velocity is sought through smoothing out of the channel's irregularities in cross section. In all such surveys we also find most convenient the use of computed sextant charts permitting the immediate plotting of observed soundings as taken.

In both the Philadelphia and New York districts, graduate officers of the Army Industrial College direct specially trained assistants in procurement planning for engineer equipment and supply in a war emergency. All of our regular officers assist in reserve training, thus keeping abreast of military progress and in touch with the Guard and Organized Reserves. From these contacts as well as with the contractors, construction superintendents, state and county engineers, our officers and their assistants are well known in the profession. In general, our

(*Continued on page 167*)

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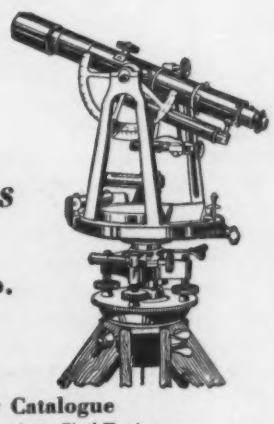

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STEELS FOR CONSTRUCTION

(*Continued from page 149*)

how materials behave under stress and the manner in which materials fail. The information which has therefore been made available has led to a more rational approach to the subject of choosing working stresses. A further broadening of this basis of our knowledge will lead to more exact designs.

To mention a few of these fields of study, the mechanism of strain-hardening by tension is now better understood and we have practical applications of this in gun manufacture and hydraulic cylinders, in which a more favorable stress condition is obtained by overstraining the material in the first instance. Recently, this same characteristic has been applied to certain bridge members. Overspeed tests of high speed rotors are another example of how a more favorable stress distribution is obtained by overstrain.

It has long been appreciated that metals when subjected to cyclic stresses can be made to fail at stress values far below what they would withstand in tension. For instance, when it is desired to break a wire this is usually done by bending backwards and forwards thereby producing fracture by fatigue rather than by the more difficult way of a direct pull.

Modern investigations by such men as Gough, Moore, Peterson, and Bacon have helped to shed further light on this kind of phenomena. In recent years, McAdam has introduced us to corrosion fatigue in which, under combined action of stress and corrosion, materials can be made to fail at stresses far below their usual fatigue strength compared to those conditions where corrosive media are not present. These tests extended recently by Inglis have shown that a mild steel specimen, whose fatigue strength when tested in air was 38,000 lbs/in^2 under corrosive conditions the safe stress could only be considered as 2,200 lbs/in^2.

The impact test, while it does not provide data which can be used in design, has found a place in many of our best material specifications largely on account of its ability to check suitability of heat-treatment. Nickel-chromium steels, when slowly cooled through a certain tempering range, give very low impact values, but, on being rapidly passed through this range by quenching, this type of undesirable brittleness disappears.

Many other points could be discussed in order to show that better materials have been produced by the concerted action of the engineer and metallurgist. Space forbids such a discussion but it may be worth while to mention one or two developments brought about by this joint action by which new steels have been made available for the engineer. Specific reference is made to the stainless steels to resist creep at high temperatures, and high yield ratio steels for statically stressed members at normal temperatures.

Considering creep resisting materials, the demands for higher and higher steam pressures and temperatures in steam turbine work, and the needs in modern oil refining work have called for better alloy steels to resist these severe conditions. In parallel with this, the engineer has also been compelled to improve his testing technique so that a better understanding of the materials used could be obtained.

For instance, it is only comparatively recently that the engineer has appreciated the importance of the time factor in tests of materials made at elevated temperature, a factor which is of little or no significance in tests made at atmospheric temperature. Since in the above applications the materials are subjected to the effects of stress and temperature over long periods of time, this effect must be known.

To show the effect of time of testing at high temperature a few results may be given. Carbon steel 0.37 percent C, has a tensile strength of 53,000 lbs/in^2 at 500° C. if the time of test is only six minutes. If the time of test be increased to 70 minutes, the strength at this temperature drops to 44,000 lbs/in^2, and if this is extended to 240 minutes this becomes 41,000 lbs/in^2. In other words, there is a continued reduction in strength with time, and consequently a new branch of testing has developed known as creep testing. The data obtained from such tests enable extension and the time to obtain such extension to be plotted, the stress and temperature being constant in a particular test. At first there is an initial extension, after which a stage is reached in which the extension is directly proportional to time. The slope of this straight-line portion will depend upon the magnitude of the stress and will decrease with decrease in stress. There is no evidence that it will become horizontal. This range is of great importance to the designer since on it depends the life of his structure. If the stress is sufficiently high, the rate of creep will again increase giving the stage of secondary creep. If this occurs, fracture usually results. With such data it has become customary to assess creep resistant steels on the basis of a given strain in a given number of hours.

These demands of the designer have been well met by the metallurgist, because in recent years many important new steels have been developed which resist this creep action much better than the usual constructional carbon or alloy steels. These steels are generally classed as the stainless variety.

It is interesting to compare one of these steels with a carbon steel on the basis of creep resisting characteristics.

TABLE IV

Steel	*Stress lbs/in^2*	*Temp.*	*Creep*
10% C to 20% C	1,000	1100° F.	1% in 10,000 hrs.
18% Cr, 8% Ni, .07% C.	11,500	1100° F.	1% in 10,000 hrs.

This shows that on the basis of 1 percent stretch in 10,000 hours, the stainless steel, which in this case is a brand known to the trade as an 18-8 steel, will withstand, at 1100° F., 100 times the stress of a low carbon steel.

Another important development in recent years has been the production of steels having a high yield ratio, this ratio being defined as the percentage which the yield point value represents of the tensile strength. Modern thought, as we have seen, has shown that the working stress for static conditions of tensile stress, such as obtained in certain bridge members and in rotating discs, should be chosen on a basis of tensile yield point values rather than as heretofore on tensile strength values. On this basis, any increase in yield ratios means that higher working stresses may be adopted with safety while the ductility is not impaired. Many of such steels are available today. To mention one of the more important of these, the Cromansil steels may be cited. This is a steel containing chromium, manganese, and silicon in percentages which fall within

Cr — 0.40 to 0.60, Mn — 1.00 to 1.40, Si — 0.60 to 0.90.

Such materials give yield point values of 50,000 lbs/in^2 with tensile values of 75,000 lbs/in^2 or a yield ratio of 67 percent against a conventional yield ratio of 50 percent for the common constructional carbon steels.

These developments in the production of new steels and a better understanding of their behavior has not been without considerable significance in industry. For instance, the overall efficiency of power generating stations has increased some 40 percent in the last ten to fifteen years. This increase is because operating superheated steam temperatures of 850° to 1000° F. is commercially possible today, and 800° to 850° F. is more or less standard practice for modern steam power plants. In 1918, the weight of an internal combustion engine necessary to produce one horsepower was 2.5 lbs. or thereabouts, but in 1936 this is nearer to one lb. or less. It is not contended that all of these savings have been the result entirely of better steels, but there is no doubt these have played a dominant part in the benefits derived.

RESEARCH IN REVIEW

(*Continued from page 155*)

that time, attention has been devoted to the development of methods of precise voltage control and accurate voltage measurement, and of a vacuum tube to withstand the voltage and to serve for the acceleration of intense beams of electrons and positive ions.

With these preliminary problems satisfactorily solved, the generator has been moved to the Institute grounds in Cambridge in order that the nuclear research program to which it will be devoted may be most effectively pursued. In designing the new generator arrangement and housing the associated Nuclear Research Laboratory in Building 46, the convenient and rapid conduct of nuclear research has been the first consideration. To this end, the generator terminals are placed in contact with electrical charging belts in one column and the discharge tube in the other. The driving motor for the belts and the bombarded target are then placed at ground potential and below ground level. This arrangement reduces the available voltage but enormously simplifies the use of detection equipment.

Preliminary bombardment work at Round Hill with a beam of electrons and a water-cooled, lead-lined target emphasized the difficulty of shielding the operators from the X-rays with the target above ground. In the present arrangement, the target is located 6 feet below ground level. The beam of most intense X-rays will be a narrow cone directed downwards to the bottom of a pit 15 feet below ground level. Thus, shielding against X-rays should be relatively simple.

All generator controls and many spare pairs for electrical circuits are brought to several control panels in the underground rooms and in Building 46 to facilitate operation at a distance. Throughout the new structure and in the alterations of the previously existing building every reasonable convenience for rapid experimental work has been included. The project is much indebted to Professor W. C. Voss and Mr. Whiston for their assistance in designing and supervising the new construction.

The derby-shaped steel building to house the generator will be of welded steel plate construction, smooth inside and stiffened outside only by a pair of welded I-beams. This building and all associated construction should be finished by the last of December. The generator will be in regular operation within a few months thereafter.

THE U. S. ENGINEER CORPS

(*Continued from page 165*)

practice is progressive and ever pioneering, thus justifying the century old motto of our corps, "Essayons".

These scattering illustrations of technique, however interesting, are definitely secondary in importance to the sound common sense methods of construction, design, and administration that have characterized Army Engineer service for generations. And by far the most valuable part of our system is the ever coming generation of junior engineers, gaining experience on all this work, crystalizing their courage, finding themselves, and preparing to meet any emergency. They are representative of the best that the country produces. Those coming from West Point — honor graduates of the Academy that is probably the most democratic of all American schools in regard to admission and initial standing — or those coming from the best engineering colleges, must pass appropriately high qualification tests. Whether they are commissioned or enter the career Civil Service, there is an open field for superior work under conditions of honor and self respect. Here is full opportunity for engineers to give their best efforts to the nation in peace on works of enduring benefit, or in war emergencies, in good company!

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EDITORIALS

(*Continued from page 153*)

long a time. Technology will no longer stand out like a sore thumb because it has no swimming pool, because its teams must play in a reconditioned World War hangar, because it can offer no home facilities to visiting athletic competitors, because its drama club, musical clubs, and debating societies have no auditorium for their own use, because it possesses only a pitifully small number of tennis courts, because there is no indoor space for the practice of soccer, lacrosse, track, and golf as there is at other institutions, because there is not enough room to care for all the men interested in rifle, basket-ball, and swimming, because it has no hall for large convocations, because its gymnasts and fencers must both try to practice in one room, because there is no ample space for purely recreational exercise, because it does not allow the fulfullment of Technology's athletic ideal of "sport for sport's sake."

Perhaps, with the new buildings "providing for all Technology men," a larger number of the students will be induced to enter extracurricular activities, either athletic or non-athletic, and become *normal* men rather than "grinds." Perhaps the recent opening of fencing to the coeds is a first step in recognizing the coeds as *normal* students. Perhaps the recent trend toward the "big" dances will lead to more natural collegiate social life. Perhaps we are witnessing what the Alumni Fund Committee has called "the big push to banish forever the bogey that Tech is hell."

THE READERS SAY:

THE Editor has received the following letters concerning the editorial *FIGHT SYPHILIS* published in the October issue:

Dear Sir:

In the last issue of T.E.N. the suggestion was made that a Wassermann test be included in the regular medical examination. Probably, in common with most editorial suggestions, this one has been already forgotten; it should not be. Why doesn't the T.E.N. conduct a questionnaire of the sort mentioned in the editorial?

Yours sincerely,
(Signed) ROBERT V. D. CAMPBELL, '38.

Dear Sir:

I liked your suggestion about Wassermann tests being made a part of the medical examination, and am willing to help in any steps the T.E.N. might take in the matter.

Sincerely yours,
(Signed) ALBERT W. BEUCKER, '40.

Dear Sir:

I think your idea of a syphilis test as part of our annual medical examination is a good one. Why not do something about it?

Yours truly,
(Signed) WARREN E. THOMSON, '38.

The T.E.N. will be happy indeed to conduct this poll of the student opinion and to deliver its results to the administration and the medical authorities.

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WHEN you approach old problems with a fresh viewpoint, you often get outstanding improvements.

For example: wires for telephone cable had long been insulated by a spiral wrapping of paper ribbon.

Refusing to accept this as the "last word," a Western Electric engineer mixed a wood pulp solution in a milk bottle—poured it on a wire—the pulp stuck. The systematic development of this idea resulted in a new and more economical insulating process—making an insulating covering of paper right on the wire! And the search for "a better way" still goes on.

Such originality leads to improved manufacturing processes and better telephone apparatus for the Bell System.

Manufacturing Plants at Chicago, Ill., Kearny, N. J., and Baltimore, Md.

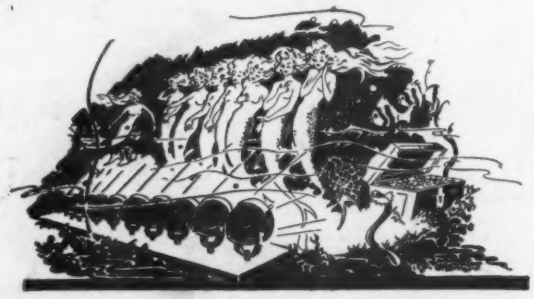
G-E *Campus News*

A 40-MILE-AN-HOUR MINE HOIST

The problem of hauling a 25-ton load up a steep mine shaft at a speed of 3,600 feet per minute, or approximately 41 miles an hour, was recently undertaken by the General Electric Company for a Southeastern coal company. Upon completion, this mine hoist will be the largest and fastest in this country.

More than 6000 feet of wire rope wound around an 18-foot drum will hoist an unbalanced load of 50,800 pounds to the surface. The driving power for this tremendous weight will be a 2500-hp G-E hoist motor with dynamic braking as a safety factor to reduce the speed when men are being carried.

For the last 40 years the General Electric Company has been engaged in the manufacture of electric mining equipment. Much of the new design and development in this field has been contributed by college-trained men who were on Test.



FLOODLIGHTING DAVY JONES' LOCKER

When Capt. John D. Craig, deep-sea diver and photographer, descends to the black depths of the Irish Channel to photograph the salvage operations of the Lusitania, Davy Jones' Locker will be floodlighted for the first time in history.

The hulk of the ill-fated Lusitania lies buried in shifting sand at a depth of approximately 300 feet, with a treasure in her coffers valued at between $4,000,000 and $15,000,000. To illuminate the wreck for filming, the General Electric Laboratories in Nela Park, Cleveland, Ohio developed a 5000-watt lamp, built to withstand a pressure of 500 pounds to the square inch—more than three times the pressure believed to be around the vessel. Capt. Craig will use a battery of 12 of these lamps mounted on a submarine stage to floodlight the inky depths.

So widespread are the uses of electricity that the development of an underwater lamp merely illustrates the problems encountered by G-E engineers. Many of these men were on the college campus but a few years ago.

MODERN LILLIPUT

Wire, three thousandths of an inch in diameter, flattened between two polished rollers to a thickness of nine ten-thousandths of an inch; pivots ground to a point and then rounded to a radius half the diameter of a human hair, yet still sharper than the sharpest needle; sapphires not as large as the head of a pin. Such Lilliputian parts are to be found in the West Lynn plant of the General Electric Company.

A pivot with a point two thousandths of an inch in diameter, yet it supports a pressure of many thousands of pounds to the square inch. Hundreds of such parts are assembled to produce instruments—instruments that measure small flows of current, great flows of current, light, sound, vibration, strain, and time. These instruments are so sensitive that they measure the smallest quantities, yet sturdy enough to withstand the severe vibrations of a locomotive cab or an airplane dashboard.

The design and manufacture of precision instruments is but one of the many fields which are open to technically trained men in the General Electric Company.

GENERAL ELECTRIC

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